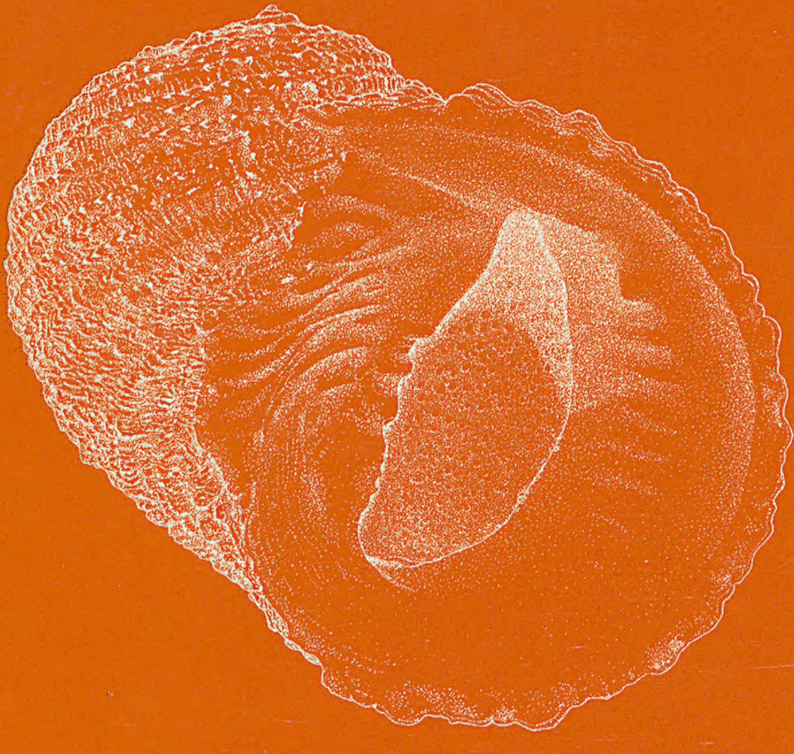
The Marine Flora and Fauna

of Darwin Harbour, Northern Australia



Edited by J.R. Hanley, G. Caswell, D. Megirian
and H.K. Larson

MUSEUMS & ART GALLERIES OF THE NORTHERN TERRITORY

AMSA
AUSTRALIAN MARINE SCIENCES ASSOCIATION

The marine flora and fauna of Darwin Harbour, Northern Territory, Australia

Proceedings of the Sixth International Marine Biological Workshop.

The marine flora and fauna of Darwin Harbour, Northern Territory, Australia

Organised by the Museums and Art Galleries of the Northern Territory and
the Australian Marine Sciences Association

Edited by J. R. Hanley, G. Caswell, D. Megirian, and H. K Larson.

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CONTENTS

PREFACE vii

LIST OF PARTICIPANTS viii

ACKNOWLEDGEMENTS ix

HOOPER, J.N.A., COOK, S.D., HOBBS, L.J. AND KENNEDY, J.A. - Australian Halichondriidae (Porifera: Demospongiae): I. Species from the Beagle Gulf. 1

COATES, K.A. AND STACEY, D.F. - Enchytraeids (Oligochaeta: Annelida) of the lower shore and shallow subtidal of Darwin Harbour, Northern Territory, Australia. 67

HEALY, B. AND COATES, K.A. - Enchytraeids (Oligochaeta: Annelida) of the mid and upper intertidal of Darwin Harbour, Northern Territory, Australia. 81

ERSÉUS, C. - The marine Tubificidae (Oligochaeta) of Darwin Harbour, Northern Territory, Australia, with descriptions of fifteen new species. 99

HUTCHINGS, P. - The Terebellidae (Polychaeta) of Northern Australia with a key to all the described species of the region.. 133

JENSEN, K.R. - Sacoglossa (Mollusca, Opisthobranchia) from the Darwin Harbour area, Northern Territory, Australia. 163

JONDELIUS, U. - A new family and three new species of flatworms (Platyhelminthes) from the Darwin Harbour area. 187

KNUDSEN, J. - Observations on some intertidal marine prosobranch molluscs from Darwin Harbour, Northern Territory. 199

WELLS, F.E. - A review of the northern Australian species of the genera *Cassidula* and *Ellobium* (Gastropoda: Ellobiidae). 213

BARTSCH, I. - Copidognathinae (Halacaridae, Acari) from northern Australia; descriptions of four new species. 231

KEABLE, S.J. - The Cirolanidae (Crustacea: Isopoda) of Darwin Harbour, Northern Territory, with additional records from northern Australia and Papua New Guinea. 245

EDGAR, G.J. - A new genus and three new species of apseudomorph Tanaidacean (Crustacea) from the Darwin region. 279

BRUCE, A.J. AND COOMBES, K.E. - An annotated check-list of the caridean shrimps (Crustacea: Decapoda) of Darwin Harbour, with descriptions of three new species of *Periclimenes* (Palaemonidae: Pontoniidae). 301

LARSON, H.K. AND WILLIAMS, R.S. - Darwin Harbour fishes: a survey and annotated checklist. 339

WOLSTENHOLME, J., DINESEN, Z.D. AND ALDERSLADE, P. - Hard corals of the Darwin region, Northern Territory, Australia. 381

ESSLEMONT, G. - Heavy metals in scleractinian corals and marine sediments from Darwin Harbour, Australia. 399

CROWE, T.P. - Epibiosis and spatial distribution of molluscs on the pylons of Mandorah Jetty, Darwin Harbour 411

CROWE, T.P. - The distribution of *Terebralia palustris* with respect to microhabitat in mangrove forests of Darwin Harbour I: Description of patterns.. 425

CROWE, T.P. AND MCMAHON, R.F. - The distribution of *Terebralia palustris* with respect to microhabitat in mangrove forests of Darwin Harbour II: Experimental evaluation of behaviour. 435

HISCOCK, P. - Archaeological evidence for environmental change in Darwin Harbour. 445

YOUSSEF, T. - Approaches in mangrove planting: some options for Darwin mangroves. 451

SMITH, A.N., HANLEY, J.R. AND LOVE, B. - Comparisons of different quadrat sizes for measuring the densities of crabs and macromolluscs of the mangrove forest floor. 461

PREFACE

Since its inception in 1982, the Northern Territory Branch of the Australian Marine Sciences Association (AMSA) has been active in promoting marine environmental issues in Northern Australia. In 1984 the Northern Territory Branch of AMSA, in conjunction with the North Australia Research Unit (NARU) of the Australian National University, jointly hosted a Conference on Coasts and Tidal Wetlands of the Australian Monsoon Region together with a Workshop on Coastal Management in Northern Australia. This was followed in 1987 by a Workshop on Research and Management in Darwin Harbour. The proceedings of the conference and workshops were published by NARU in their *Mangrove Monograph* series (No. 1 and No. 2, 1985; No. 4, 1988).

Much of the work of marine scientists in the region has focussed on Darwin Harbour, an area that is significant not only because it is the main population centre for the Northern Territory and an important recreational and commercial resource, but also because of its unique natural features which include one of the largest single stands of mangroves in Australia.

Darwin Harbour or Port Darwin is a large shallow drowned river valley system. Encompassing an area of about 1,000 square km, the Harbour is characterised by a macrotidal regime (7m spring tidal range) and an extensive shallow intertidal zone dominated by mangrove communities which extend over about 20,000 hectares in area. Subject to a strong monsoonal weather pattern, the Harbour waters are generally warm (23 to 33°C) and turbid, with heavy rainfall during the wet season (November to April) and river runoff contributing to high nutrient and sediment loads. These physical factors have a profound affect on the biota and Darwin Harbour supports a remarkably high diversity and biomass of filter-feeding benthic invertebrate assemblages.

The city of Darwin lies on the north-eastern side of the Harbour. Darwin has a residential population of approximately 73,000 people. Urbanisation has developed largely around the harbour peninsula, and more recently out to the regional centre of Palmerston. Although Darwin is a capital city, it does not yet have any heavy industry and most of the environmental impacts have been concentrated near the city and East Arm of the Harbour. The major impacts have been from clearing of mangroves and infilling of intertidal land, although these are insignificant compared with southern States.

While much of Darwin Harbour can be considered pristine, increased population growth, urbanisation of the shoreline and industrial development pose potential threats to the Harbour. For this reason there has been strong interest in recent years in studies aimed at providing baseline information for the future management of this large natural resource.

In July 1993 the Northern Territory Branch of AMSA, together with the Museum and Art Gallery of the Northern Territory, organised an International Workshop on the Marine Biology of Darwin Harbour. This Workshop, the sixth in a series of International Marine Biological Workshops, brought together more than 30 participants from the Northern Territory, Western Australia, Tasmania, New South Wales, Canada, Indonesia, the United States, Ireland, Sweden and Denmark for 19 days of intensive study of the marine flora and fauna of Darwin Harbour. The present proceedings reports on the scientific work done at the Darwin Harbour Workshop, and includes 22 research papers. These cover the taxonomy and systematics, ecology, behaviour, and physiology and functional morphology of the marine flora and fauna of Darwin Harbour.

Dr Barry C. Russell

President, Northern Territory Branch
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The Museum and Art Gallery of the Northern Territory (MAGNT) provided logistic and financial support for the Workshop and was instrumental in preparing the results for publication. We are particularly indebted to Ms Helen Larson and Dr Dirk Megirian for their editorial support; Mrs Lorna Gravener for manuscript typing and corrections; and Mr Neil Smit for typesetting.

The Workshop could not have taken place without the additional financial support of the Australian Geographic Society, the Australian International Development Assistance Bureau, the Commonwealth Environment Protection Agency, Mount Isa Mines, and the Power and Water Authority. In kind support also was received from the Conservation Commission of the Northern Territory, Northern Territory University (NTU), and the Power and Water Authority.

Special thanks are due to Peter Jordan, Manager of the Mandorah Beachside Hotel, where the Workshop was held. Peter put up with numerous odd requests and habits of scientists at the Workshop.

Captain Arthur (Mouse) Beckhouse, Daniel Low Choy, Roger Lau, and Rex Williams of MAGNT and Ron Gilmore of NTU provided essential boat support. Volunteers Paul Buck, Sylvia Francis, Ruth Garden, Christopher Johnson, Chris Jones, Lisa Knight, Katerina Koulakis, Barbara Love, Helen Prichard, and Charlene Stevens, assisted with field work and helped with individual research projects and greatly contributed to the success of the Workshop.

The participation of individual researchers was supported by a variety of funding bodies which are acknowledged in individual papers; the organisers are grateful to all. All papers were individually refereed by two referees. The referees were very helpful in assisting enhance the quality of the proceedings, and we are grateful for their help.

The Northern Territory Minister for Conservation, the Hon. Mike Reed, formally launched the Workshop at a ceremony hosted by the then Chief Minister of the Northern Territory, the Hon. Marshall Perron; we deeply appreciate their support and that of the Northern Territory Government.

J. Russell Hanley and Gabi Caswell

Organisers, Sixth International Marine Biological Workshop.

AUSTRALIAN HALICHONDRIIDAE (PORIFERA: DEMOSPONGIAE): I. SPECIES FROM THE BEAGLE GULF.

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ABSTRACT

Twenty species of sponge in seven genera of the family Halichondriidae (order Halichondrida) are described from the Beagle Gulf, Darwin region, Northern Territory, including eight new species and five new records for Australia. A resumé is provided of generic characters and a survey of the known Indo-west Pacific species in these genera.

KEYWORDS: Porifera, Demospongiae, Halichondriidae, *Axinyssa, Myrmekioderma, Topsentia, Ciocalypta, Amorphinopsis, Halichondria, Hymeniacidon*, taxonomy, new species, northwest Australia.

INTRODUCTION

Of the 114 families of extant Porifera only two (Raspailiidae and Microcionidae, order Poecilosclerida) can so far be considered well known in the Australian fauna (Hooper 1991, 1996). In this present work we deal with a third family, Halichondriidae, in the order Halichondrida.

Traditional definitions of Halichondrida were based on the possession of diactinal megascleres, a relatively homogenous skeletal structure described as 'halichondroid' (criss-cross reticulate), viviparous reproduction and completely ciliated larvae (Bergquist 1978; Hartman 1982). Under this interpretation two families were differentiated, Halichondriidae Vosmaer, 1887 (principal megascleres oxeas sometimes also with accessory styles), and Hymenacidonidae de Laubenfels, 1934 (principal megascleres styles sometimes with accessory oxeas), (Bergquist 1978). A recent revision of the order by Van Soest *et al.* (1990) allowed for the inclusion of species with compressed axial skeletons, differentiated axial and extra-axial skeletons (i.e. traditional Axinellidae), an indiscriminate occurrence of styles and oxeas within the skeletons, as well as 'typical' halichondrids with skeletal arrangements of styles or oxeas in plumose to ill-defined, confused tracts. Four families were subsequently included in the order (Halichondriidae, Axinellidae, Dictyonellidae and Desmoxyidae), although there is not yet complete agreement about the generic composition of each of these (see Hooper and Lévi 1993b).

In its initial conception, Halichondriidae contained 27 very disparate genera allegedly related to each other by their possession of "fusiform or pin-shaped spicules variously fasciculated together" (Gray 1867: 503). Apart from *Halichondria* and *Ciocalypta*, all the other genera included here by Gray (1867) were subsequently assigned by contemporary authors to Poecilosclerida, Hadromerida or Haplosclerida. Nevertheless, the family name remains valid for the current assemblage of genera containing the genus *Halichondria* (Article 40 ICZN; Anon. 1985). Few subsequent authors used the family name Halichondriidae until it was redefined by de Laubenfels (1936) in a contemporary classification, after which time it came into general acceptance (e.g. Lévi 1973; Berquist 1978; Hartman 1982). De Laubenfels' (1936: 133) interpretation of the family included eight genera, of which several were clear synonyms, all with "exceedingly simple spiculation ... of ... only oxeas ... smooth ... without microscleres ... [with] special dermal skeletons, although these are not conspicuous" (i.e. it specifically excluded sponges like *Hymeniacidon* with principal styles rath-

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er than oxeas and a fleshy, gelatinous consistency). De Laubenfels (1936) further characterised the family in having "subdermal cavities ... so very enormous that the dermis is merely a roof supported on slender columns ... above ... the endosome".

Since its creation, 54 genera have been associated with the Halichondriidae, although the most recent revision by Van Soest *et al.* (1990) (with subsequent refinements by Diaz *et al.* (1991, 1993) and Pomponi *et al.* (1991)), now recognises only 12 of these (the remainder being junior synonyms or incorrect assignments): *Amorphinopsis* Carter, *Axinyssa* Lendenfeld, *Ciocalypta* Bowerbank, *Collocalypta* Dendy, *Didiscus* Dendy, *Epipolasis* de Laubenfels, *Halichondria* Fleming, *Hymeniacidon* Bowerbank, *Myrmekioderma* Ehlers, *Petromica* Topsent, *Spongosorites* Topsent and *Topsentia* Berg. All these genera have a highly dense choanosomal spicule skeleton arranged in vague, directionless (halichondroid) tracts composed of spicules in confusion (Van Soest et al. 1990), with spicules being either principal oxeas or styles, sometimes also with smaller accessory styles or oxeas (i.e. including Hymeniacidonidae and some Axinellidae). The Halichondriidae now represents one of the few spicule-bearing ('non-keratose') families of Porifera 'accessible' to contemporary systematics.

So far only 28 species in eight of the 12 halichondriid genera have previous published records from Australian territorial waters (including Antarctica) (Hooper and Wiedenmayer 1994), and surprisingly only two of these came from the northwest Australian region.

In the present work we describe 20 species in seven genera from the Beagle Gulf, of which five are new records for Australia and eight are new species. A second contribution describing halichondriids from other tropical Australian provinces is currently in progress (Hooper et al. in prep.).

DARWIN SPONGE FAUNA

In this forum (i.e. The International Workshop on the Flora and Fauna of Darwin Harbour) it is appropriate to summarise existing knowledge on the Darwin sponge fauna of the greater region, namely the Beagle Gulf.

The sponge fauna of northwest Australia is possibly the most diverse of all Australian marine provinces, with about 800 species already collected from this region (extending from Northwest Cape, WA, to the Wessel Islands, NT; Hooper unpublished data), but so far less than 300 of these have been named in the literature (Hooper and Wiedenmayer 1994). Many species are unique to this region, with levels of endemism in some families thought to be about 70% (Hooper and Lévi 1994), although for most sponge families this fauna is still poorly known. Habitats within this region are also incredibly diverse, most with at least some sponge species represented (ranging from ephemeral pockets of freshwater, large rivers, euryhaline estuaries and extensive mangroves, mud flats, fringing intertidal and subtidal rock and coral reefs, seagrass and *Halimeda* beds, artificial substrates, sand, coral rubble and shell-grit bottoms, deeper offshore rock reefs, submerged 'active' coral reefs, as well as pristine emergent platform and fringing coral reefs).

There have been several major publications on sponges within the Beagle Gulf but prior to the present work only 71 species have been described. The earliest authenticated record of this fauna comes from material collected between 1875 and 1877 by T.J. Sturt, which was sent to Melbourne and initially described as a 'curiosity' (Barnard 1879), but subsequently identified by Carter (1879) as an endemic genus and species, *Axos flabelliformis* Carter (Hooper 1986a). In 1881 the British survey ship HMS *Alert* made extensive collections of the fauna, mostly dredging shallow waters within Darwin Harbour, Van Diemen Gulf, Dundas Strait and the Timor Sea. The sponges from this collection were described by Ridley (1884), and included 24 species, 21 named and three left uncertain, of which only 17 are currently recognisable as valid species. Nine of these species have not since been recorded elsewhere (i.e. apparent endemics).

In the early 1960's a team from the Australian Museum, Sydney, led by Elizabeth Pope, travelled to Darwin, Cape Don and Port Essington to survey the intertidal marine biology of this region. This collection is the earliest comprehensive attempt to document the marine invertebrates of the northwest Australian coast (Pope 1967), from which the sponge fauna was described separately (Bergquist and Tizard 1967). These authors described 19 species of the larger, more prevalent intertidal sponges found in this region, belonging to 17 genera and with three new species.

Since 1967, there have been 37 additional species in 16 genera described from the Beagle

Gulf region (Darwin Harbour in particular), as well as from other parts of the NT and northern WA coasts, including notes on the ecology, biochemistry and/or biogeographical relationships of several species (Hooper 1984, 1986a, 1986b, 1987, 1991, 1994; Hooper and Bergquist 1992; Hooper and Lévi 1993a, 1993b, 1994; Hooper et al. 1990, 1991, 1992; Capon et al. 1986; Capon and MacLeod 1988; Cambie et al. 1988a, 1988b; Van Soest et al. 1991). Significantly, Darwin Harbour is the type locality for 22 of these species, most discovered originally from the East Point Aquatic Reserve. Nevertheless, this described fauna represents less than 10% of the species known to live in the Beagle Gulf, and it is anticipated that this list of published species will increase substantially over the next decade.

METHODS

Methods of collection, preservation, histological preparation, and techniques for light microscopy and scanning electron microscopy are given elsewhere (e.g. Hooper 1991). Spicule measurements are based on 25 measurements of each category of spicule, and represented as range (and mean). Abbreviations used in the text are: AM, Australian Museum, Sydney; BMNH, The Natural History Museum, London; CCNT, Conservation Commission of the Northern Territory, Darwin; MNHN, Muséum National d'Histoire Naturelle, Paris; NCI AIMS, Australian Institute of Marine Science (US National Cancer Institute collection contract, 1985-1991); NCI CRRF, Coral Reef Research Foundation, Chuuk State, Federated States of Micronesia (US National Cancer Institute collection contract, 1992); NT, Northern Territory; NTM, Northern Territory Museum, Darwin; QM, Queensland Museum, Brisbane; SMF, Natur-Museum und Forschungsinstitut Senckenberg, Frankfurt; WA, Western Australia; ZMB, Museum für Naturkunde an der Humboldt-Universität zu Berlin.

SYSTEMATICS

Order Halichondrida Vosmaer

Halichondrida Vosmaer, 1887: 335.

Diagnosis. Demospongiae with plumoreticulate skeletal architecture composed of relatively large oxeas, styles, strongyloxeas or intermediate spicules not functionally localised to any particular region of skeleton. Spicules widely diverging in size in some taxa, sometimes with size differences between ectosomal and choanosomal skeletons. Skeletal structures ranging from disorganised plumoreticulate, criss-crossed "halichondroid skeleton", to distinctly compressed axis (or basal) skeleton and differentiated extra-axial (radial, plumose or plumoreticulate) skeleton. Spongin fibres usually poorly developed or absent. Ectosomal skeleton organised into tangential layer of spicules or erect spicule bundles, with minimal collagen, and large subectosomal spaces in many taxa. Microscleres raphides, microxeas, or spined microxeas with central bend in some species.

Family Halichondriidae Gray

Halichondriadae Gray, 1867: 503.

Halichondriidae; Vosmaer, 1887: 336. - de Laubenfels 1936: 133; - Van Soest *et al.* 1990: 20.

Ciocalyptidae Hentschel, 1923: 408.

Spongosoritidae Topsent, 1928: 35,157.

Petromicidae Topsent, 1928: 34,105.

Hymeniacidonidae de Laubenfels, 1934: 13.

Diagnosis. Halichondrida with choanosomal skeleton consisting of high density of spicules arranged in vague, ill-defined, directionless tracts and spicules in confusion. Ectosomal skeletons frequently detachable, often composed of spicules of different size than those in choanosome. Spicules are relatively large oxeas and/or styles, sometimes strongyloxeas or intermediate spicules

Genus *Axinyssa* Lendenfeld

Axinyssa Lendenfeld, 1897: 116.

Pseudaxinyssa Burton, 1931: 350.

Axinomimus de Laubenfels, 1936: 163.

Type species. *Axinyssa topsenti* Lendenfeld, 1897, by monotypy.

Diagnosis. Massive, subspherical, lobate or lobate-digitate growth forms, often with apical cloacal cavity and fistulose surface processes. Choanosomal skeleton collagenous (although spongin fibres poorly developed), with widely spaced spicule tracts cored by larger oxeas, largely strewn in confusion or slightly plumose, dendritic or vaguely radiating. Subectosomal skeleton more organised than choanosomal region, plumose or plumo-reticulate, with regular tracts of larger choanosomal oxeote megascleres ascending to surface; without fibre component but with heavy collagenous mesohyl. Ectosomal skeleton highly collagenous, with mineral skeleton composed of smaller oxeote spicules forming discrete, sparse, regularly distributed surface brushes eventually producing surface conules; or of larger choanosomal oxeotes protruding through surface and producing regularly spaced surface conules. Megascleres are one or two size categories of oxeas or modified (styloid, strongyloid) oxeotes.

Remarks. *Axinyssa* and the related genus *Collocalypta* differ from other halichondriids in having choanosomal spicule tracts protruding slightly through a largely organic ectosome (i.e. lacking a continuous ectosomal skeletal crust), producing a finely conulose surface (Van Soest *et al.* 1990). *Axinyssa* differs from the latter genus by its plumose or vaguely plumoreticulate skeletal structure (particularly near the surface), and growth form (the latter being exclusively fistulose). The emended diagnoses and discussions given by Van Soest *et al.* (1990) and Hooper and Bergquist (1992) clearly differentiate the two genera, whereas the diagnosis provided by Diaz *et al.* (1991) did not, mainly because they did not encounter *Collocalypta* in the central Atlantic fauna. Worldwide there are so far 13 described species of *Axinyssa*, distributed throughout the tropical oceans in shallow reefs to deeper coastal waters, but only one of these have been previously described from Indo-Australian waters: *A. aplysinoides* (Dendy) described from the Great Barrier Reef (Burton 1934).

Axinyssa aplysinoides (Dendy)
(Figs 1-2)

Halichondria aplysinoides Dendy, 1922: 39-40, pl. 3, figs 3-5, pl.12, fig. 9.

Trachyopsis aplysinoides - Burton, 1926: 78; - Burton 1934: 564.

Axinyssa aplysinoides - Van Soest *et al.*, 1990, fig. 20; - Hooper and Bergquist 1992: 101.

Type material. HOLOTYPE - BMNH 1921.11.7.31: Cargados Carajos, Indian Ocean, 30 August 1905, 58m depth, coll. HMS *Sealark*.

Material. QM G303561: Outer region of Shoal Bay, NT, 12°06.9'S, 130°49.9'E, 18 m depth, 12 October 1993, coll. CCNT stn. 136 (ref. 2176), dredge.

Distribution. Cargados Carajos, Amirante, Coetivy, Egmont Reef, Seychelles Is, Indian Ocean; southeast Indonesia; Satellite Reef, Great Barrier Reef; Shoal Bay, Timor Sea, NT.

Habitat. Sponge bed, soft mud and shell-grit substrate; subtidal 18-200 m depth.

Description. Massive, lobate, with lumpy appearance, approximately 55 mm diameter. Oscules large, up to 4 mm in diameter, discrete, scattered over entire surface (i.e. not confined to apex of sponge), flush with surface (i.e. without raised membraneous lip).

Colour. Pale pinkish alive in air (Munsell 5RP 8/2); ectosome purple-grey in ethanol, with lighter choanosome.

Texture. Firm, resilient, barely compressible; not easily broken.

Surface. Irregular surface with incorporated detritus; minutely hispid, with series of small raised ridges running over surface forming minute reticulation. Cavernous subectosomal skeleton visible through transparent surface membrane.

Ectosomal skeleton. Plumose bundles of larger spicules from subectosomal region protrude through collagenous layer at surface, forming brushes or singly, with sparse tangential layer of both smaller and larger spicules, lying singly or in paucispicular tracts, overlaying ascending subectosomal skeleton.

Choanosomal skeleton. Confused halichondroid reticulation of multispicular tracts in deeper choanosomal region of skeleton, becoming slightly more organised towards periphery; multispicular choanosomal skeletal tracts composed 20-50 spicules wide, ascending towards surface, becoming more plumose in subectosomal region, tracts separated by large subectosomal cavities of approximately same width as tracts themselves. Spongin fibres not evident. Collagen abundant in choanosomal mesohyl, associated predominantly with spicule tracts. Generally all spicule sizes dispersed throughout ectosomal and choanosomal skeletons, without clearly differentiated ectosomal and choanosomal size classes, although smaller spicules mainly found scattered between tracts whereas larger spicules mainly aligned in tracts.

Spicules. Oxeas in two size classes, or more probably one class with large size range: larger oxeas slightly curved at centre, hastate relatively abruptly pointed (length 550-(622.4)-744 µm, width 13-(16.8)-21 µm); smaller oxeas straight or slightly curved, hastate abruptly pointed, occasionally styloid (length 188-(241.4)-290 µm, width 4-(6.7)-11 µm).

Remarks. This species has not previously been recorded having two size classes of oxeas, although Dendy (1922) notes that the main

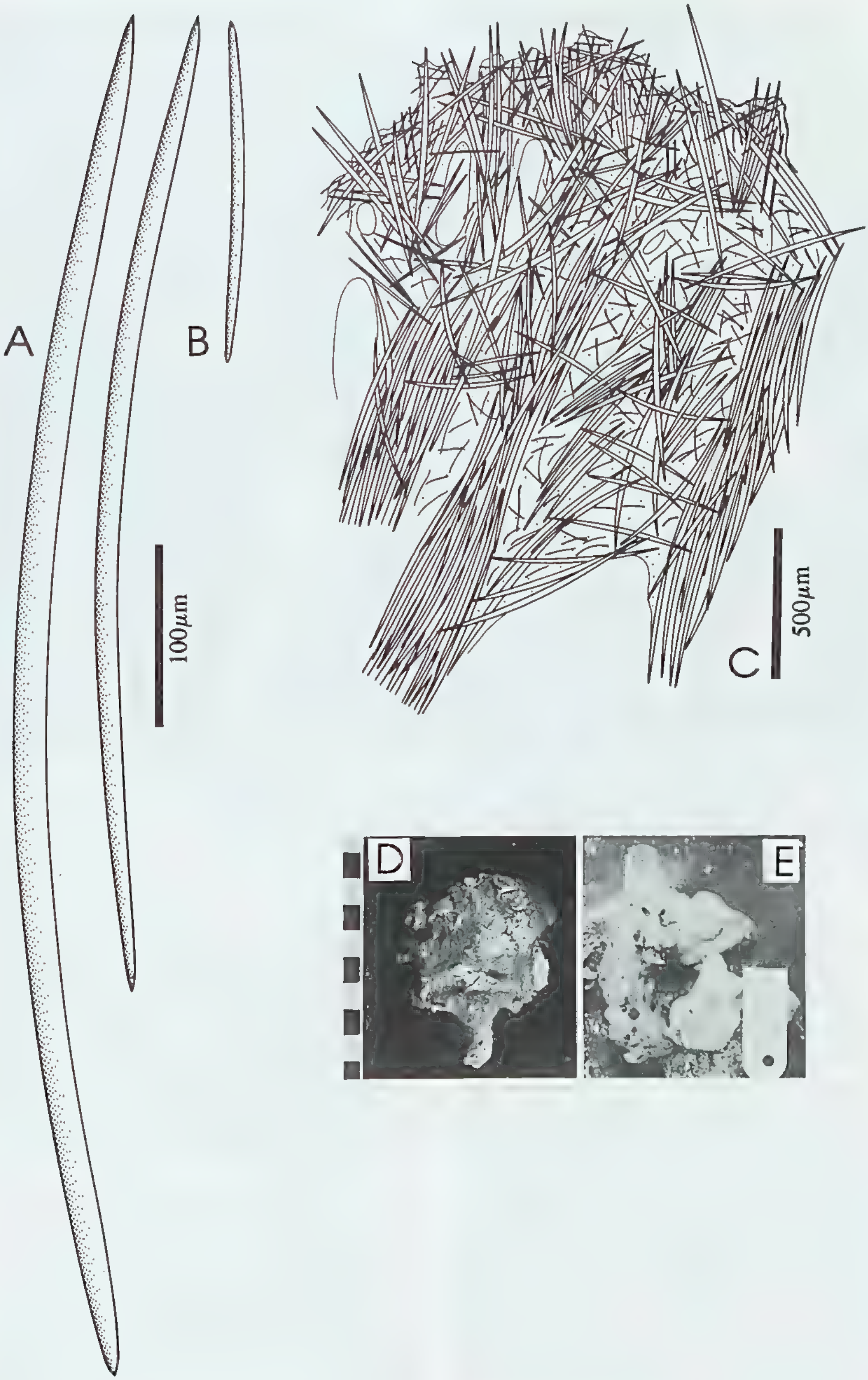

Fig. 1. *Axinyssa aplysinoides* (Dendy). **A,** larger oxeas; **B,** smaller oxea. **C,** peripheral skeletal structure; **D,** preserved specimen QM G303561; **E,** live specimen (on deck).

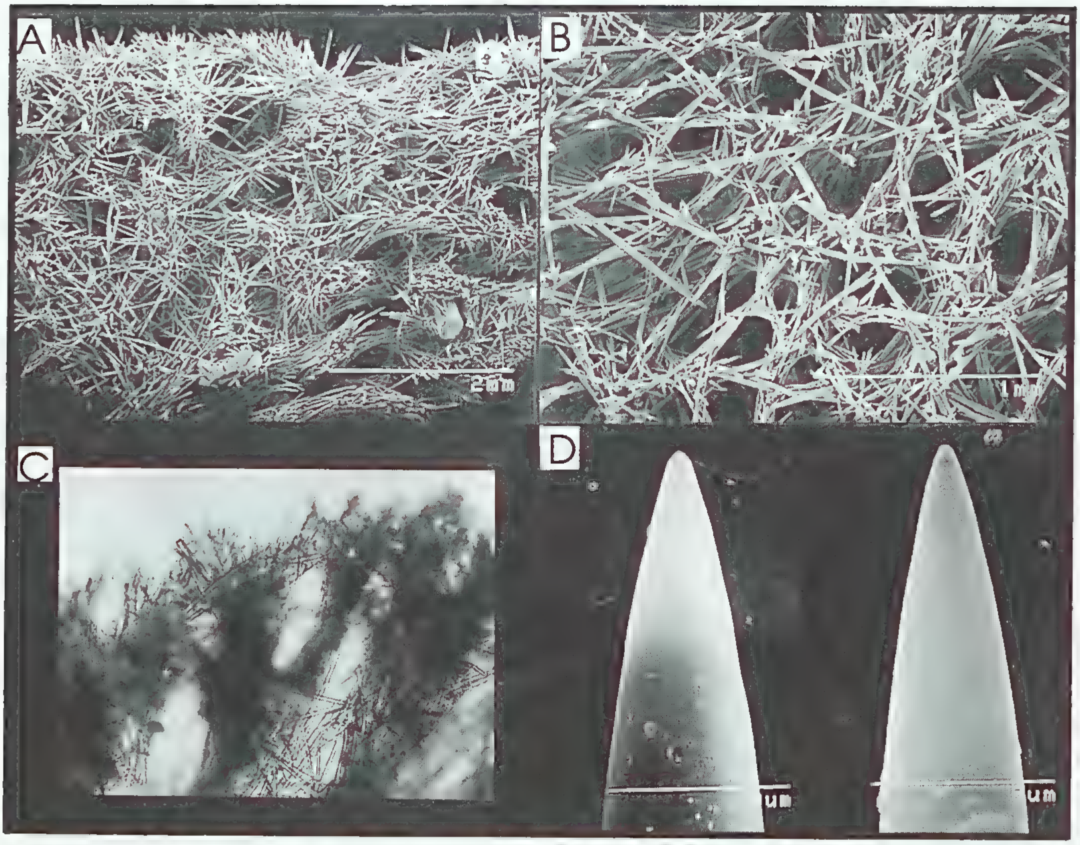

Fig. 2. *Axinyssa aplysinoides* (Dendy). Specimen QM G303561. **A,** Perpendicular section through skeleton showing large multispicular tracts in choanosomal skeleton, becoming more plumose in periphery; **B,** transverse section of ectosomal skeleton showing outer surface of sponge with tangential uni- and paucispicular tracts of both larger and smaller oxeas; **C,** light micrograph of section through peripheral skeleton showing plumo-reticulate subectosomal skeletal tracts and protruding larger spicules; **D,** hastate pointed spicule terminations on both larger oxeas (left) and smaller oxeas (right).

megascleres "vary considerably in size", with the upper size limit of 1000 x 30 µm. In the Darwin specimen, spicules are indiscriminantly scattered throughout the skeleton, without any marked localisation of spicule sizes to either ectosomal or choanosomal regions (unlike those of *Topsentia* or *Epipolasis* which have their ectosomal skeletons composed of a distinctly smaller category of spicules), and it is possible that smaller megascleres seen here (mostly scattered between the major spicule tracts) are juvenile forms of the main structural spicules.

Dendy (1905) suggests that the most distinctive feature of this species is its resemblance to an *Aplysina* (Verongida) in external morphology, in particular to the series of minute, raised ridges forming a reticulation on the surface. These surface features, together with the ascending multispicular tracts of oxeas cemented together by granular collagen, and the spicule geometry (lacking telescoped points, occasionally styloid ends), differentiate this species from other *Axinyssa*. We do not know whether material from the Great Barrier Reef recorded by Burton (1934) is similar to the Darwin specimen, described above, as Burton did not describe his specimen, but it is assumed that conspecificity of his specimen was checked against type material given that he had easy access to the holotype in the BMNH collection.

Genus *Myrmekioderma* Ehlers

Myrmekioderma Ehlers, 1870: 28.
Acanthoxifera Dendy, 1905: 156.
Anacanthaea Row, 1911: 329.
Neoprosypa de Laubenfels, 1954:189.

Type species. *Alcyonium granulatum* Esper, 1830: 71.

Diagnosis. Massive or encrusting growth forms. Surface hispid, with characteristic excavating meandering, sinuous or straight canals and grooves (forming polygonal tuberculate plates in type species). Choanosomal skeleton collagenous, with compressed central portion composed of confused mass of larger spicules forming irregular, ascending, multispicular tracts bound together with collagen (spongin fibres present in some species but not all). Subectosomal skeleton composed of ascending tracts running radially or obliquely to surface. Ectosomal skeleton dense paratangential layer of smaller spicules forming closely adjacent brushes perpendicular to surface, with larger choanosomal spicules also protruding. Megascleres at least two distinct categories of choanosomal oxeas, strongyles, or more rarely styles, sometimes sinuous and centrally flexed, and smaller ectosomal oxeas or acanthoxeas of similar morphology. Microscleres raphides in trichodragmata, in one or more categories, larger usually sinuous or curved.

Remarks. Recent revisions of this genus are provided by Bergquist (1965: 177), Van Soest *et al.* (1990: 31), Diaz *et al.* (1991) and Hooper and Lévi (1993b: 1448). *Myrmekioderma* and *Didiscus* are apparently related (and both easily recognisable in the field) by their deeply sculptured sinuous and plate-like grooves on the surface, having an ectosome composed of smaller spicules forming an erect palisade over tangential larger spicules, and a similar basic choanosomal skeletal organisation (Van Soest *et al.* 1990; Diaz *et al.* 1991). *Myrmekioderma* lacks discorhabd microscleres, characteristic of *Didiscus*, but has instead bundles of sinuous raphides (trichodragmata). The genus has been traditionally defined with lightly acanthose ectosomal oxeas (e.g. Bergquist 1965; Hooper and Lévi 1993b), but Diaz *et al.* (1991) correctly note that these ectosomal spicules are as frequently smooth as they are acanthose, and they emend the definition accordingly. Hooper and Lévi (1993b) retained this genus in the family Desmoxyidae, supporting their decision with chemotaxonomic evidence based on an inferred close relationship between *Higginsia* and *Myrmekioderma* (Hooper *et al.* 1992). However, there is no strong morphological support for homology between the occasionally acanthose ectosomal oxeas in *Myrmekioderma* and the true ectosomal acanthoxeas in *Higginsia*. The overall similarity between the ectosomal structure, choansomal organisation and spicule composition (apart from the possession of microxeas or discorhabds, respectively) largely supports the inferred close relationship between *Myrmekioderma* and *Didiscus* and their inclusion in Halichondriidae, as proposed by Van Soest *et al.* (1990). However, it must be acknowledged that structural similarities in the erect palisade of ectosomal spicules is remarkable between *Myrmekioderma* and *Higginsia* (see illustrations in Hooper and Lévi 1993b), for which genetic data might provide a more informed opinion.

Myrmekioderma is widespread in shallow tropical and subtropical oceans, found predominantly on hard substrates, sand and rubble substrates. One species, *M granulata*, has been recorded previously from northwest Australian and southern Indonesian waters (Van Soest *et al.* 1990; Hooper and Lévi 1993b), and is thought to be one of the truly widespread coral reef sponges throughout the Indo-west Pacific (Hooper 1994).

Myrmekioderma granulata (Esper, 1830)
(Figs 3-4)

Alcyonium granulatum Esper, 1830: 71, pl. 24.

Myrmekioderma granulata; - Ehlers, 1870:28; - Burton 1938: 39, pl.7, fig. 42; - de Laubenfels 1954: 121, fig. 75; - Lévi 1961: 14, fig. 17; - Bergquist 1965: 177, fig.27a-b; - Van Soest *et al.* 1990: 29, fig. 28; - Hooper *et al.* 1992: 265; - Hooper and Lévi 1993b: 1449, figs 35-36.

Acanthoxifer ceylonensis Dendy, 1905: 157, pl. 9, fig. 5; - Dendy, 1922: 129.

Myrmekioderma tylota de Laubenfels, 1954: 119, fig. 74.

Neoprosypa atina de Laubenfels, 1954: 190, fig. 127.

Acanthoxifer fourmanoiri Lévi, 1956: 5.

Material. NTM Z196: Dudley Point reef flat, East Point, Darwin Harbour, NT, 12°25.0'S, 130°49.01'E, 0-0.5 m depth, 13 September 1981, coll. J.N.A. Hooper and P.N. Alderslade, by hand. NTM Z2053: Dudley Point reef slope, Darwin Harbour, 12°25.0'S, 130°48.40'E, 6-10 m depth, 10 May 1984, coll. J.N.A. Hooper and P.N. Alderslade, SCUBA. QM G303349: East Point 'bommies', 12°24.5'S, 130°48.8'E, 10 m depth, 23 September 1993, coll. J.N.A. Hooper, L.J. Hobbs and B. Alvarez, SCUBA. NTM Z430: Lee Point, Darwin, 12°19.02'S, 130°53.01'E, 0-0.2 m depth, 13 December 1981, coll. J.N.A. Hooper, by hand.

Comparative material (Refer to Hooper and Lévi 1993b: 1449 for additional material examined). QMG300819: W of Port Musgrave, Gulf of Carpentaria, Qld 12°04.6'S, 139°21.5'E, 54 m depth, 25 November 1991, coll. S. Cook, RV *Southern Surveyor*, dredge. QMG303505: W of Duyfken Point, 12°28.4'S, 141°00.8'E, 53 m depth, 6 November 1993, coll. S.D. Cook and J.A. Kennedy, RV *Southern Surveyor*, trawl. QMG303172: NE side Flinders Reef, N. of Moreton I., SE Qld, 26°58.6'S, 153°29.2'E, 9 m depth, 31 May 1993, coll. J.N.A. Hooper, SCUBA. QMG303135: Lagoon, Truk Atoll, Caroline Is, 7°24.9'N, 151°44.4'E, 31 m depth, 24 March 1992, coll. NCI (CRRF).

Distribution. Dudley Point, East Point, Lee Point, Darwin Harbour, NT; Port Essington, Cobourg Peninsula; Cumberland Strait, Wessel Is, NT; Parry Shoals, Arafura Sea, NT; Enderbry I., Direction I., Dampier Archipelago, WA; Hibernia Reef, Sahul Shelf, Territory of Ashmore and Cartier; Moreton Bay region, Qld; western Gulf of Carpentaria, Qld; Madagascar, Aldabra, Seychelles, Gulf of Manaar, SE Indonesia, Ponape, Truk (Chuuk), Ebon Atolls, Palau, Ifaluk, Chesterfield Is (refer to references in Hooper and Lévi 1993b).

Habitat. Shallow-water rock and coral platforms, coral pools, coral rubble, usually heavily sedimented, or in spur-and-grooves of fringing reefs; in deeper water found on exposed reef heads in gravel and mud substrates; intertidal to subtidal depths of 60 m.

Description. Massive, subspherical or elongate bulbous, up to 1 m long, 1 m wide, 0.5 m thick; partially burrowing in soft sediment or excavating coralline substrate. Oscules large, discrete, conspicuous, usually situated in excavated grooves on apical surface, and each oscule with raised lip.

Colour. Bright orange to dark orange-brown exterior (Munsell 7.5YR 7/10-5YR 6/10), often silt-covered in life; paler orange-yellow interior; orange-brown in ethanol.

Texture. Firm but compressible, harsh with hispid surface; interior soft, producing mucus.

Surface. Opaque and membranous, covered by rounded, raised polygonal plates separated by grooves and canals, producing pineapple-like external surface.

Ectosomal skeleton. Detachable; distinct crust of smaller ectosomal spicules forming continuous paratangential palisade, associated with and protruding through heavy collagenous ectosomal layer, and dispersed amongst larger choanosomal oxeas and styles, the latter more-or-less erect and ascending to surface. Subectosomal region dense, collagenous, cavernous in places, with tracts of larger choanosomal oxeas supporting ectosomal crust.

Choanosomal skeleton. Skeletal structure vaguely halichondroid reticulate, with compressed central portion, oblique subectosomal skeletal tracts supporting paratangential ectosomal layer. Choanosomal spicule tracts composed of up to 50 choanosomal spicules abreast, ascending to surface, becoming both sparser and more confused in peripheral skeleton. Thick fibres visible only in some specimens (being fully cored by spicules in others), with differentiated primary, multispicular, ascending fibres and transverse paucispicular fibres. Fibre meshes up to 300 µm diameter. Collagen abundant, very granular and pigmented in choanosome. Choanocyte chambers small, oval, 40-70 µm diameter.

Spicules. Two size classes of megascleres recognised: choanosomal and ectosomal; variable megasclere geometry, ranging from fusiform oxeas, strongyloxeas, strongyles or styles; spicule terminations range from pointed to telescoped, styloid or sometimes with terminal deformities; and spicules may be completely smooth or lightly and evenly acanthose (Berguist 1965). In Beagle Gulf populations choanosomal megascleres predominantly oxeas, less often strongyloxeas or styloid, usually larger than ectosomal spicules, often with microspination (length 495-(615.7)-950 µm, width 8-(18.2)-22 µm). Smaller ectosomal megascleres invariably oxeote, predominantly smooth but occasionally evenly microspined (length 305-(502.4)-580 µm, width 3-(7.5)-10 µm).

Microscleres raphides in bundles (trichodragmata) (110-155 x 10-15 µm).

Remarks. Live specimens of *M. granulata* are distinctive in their characteristic dark orange colouration, mango-like texture, massive growth form and plate-like surface ornamentation. The species is now relatively well documented and known to be widely distributed within the Indo-west Pacific region, extending from Madagascar to NW Australia, Indonesia and the central west-Pacific islands and atolls (Esper 1830; Ehlers 1870; Dendy 1905, 1922; Burton 1938; Lévi 1956, 1961; de Laubenfels 1954; Bergquist 1965; Van Soest *et al.* 1990). In the southwest Pacific the species is rare, so far known only from isolated records (Flinders Reef off Moreton Bay (27°S) and Chesterfield Islands (21.5°S latitude; Hooper and Lévi 1993b and unpublished data). Surprisingly, the spe-

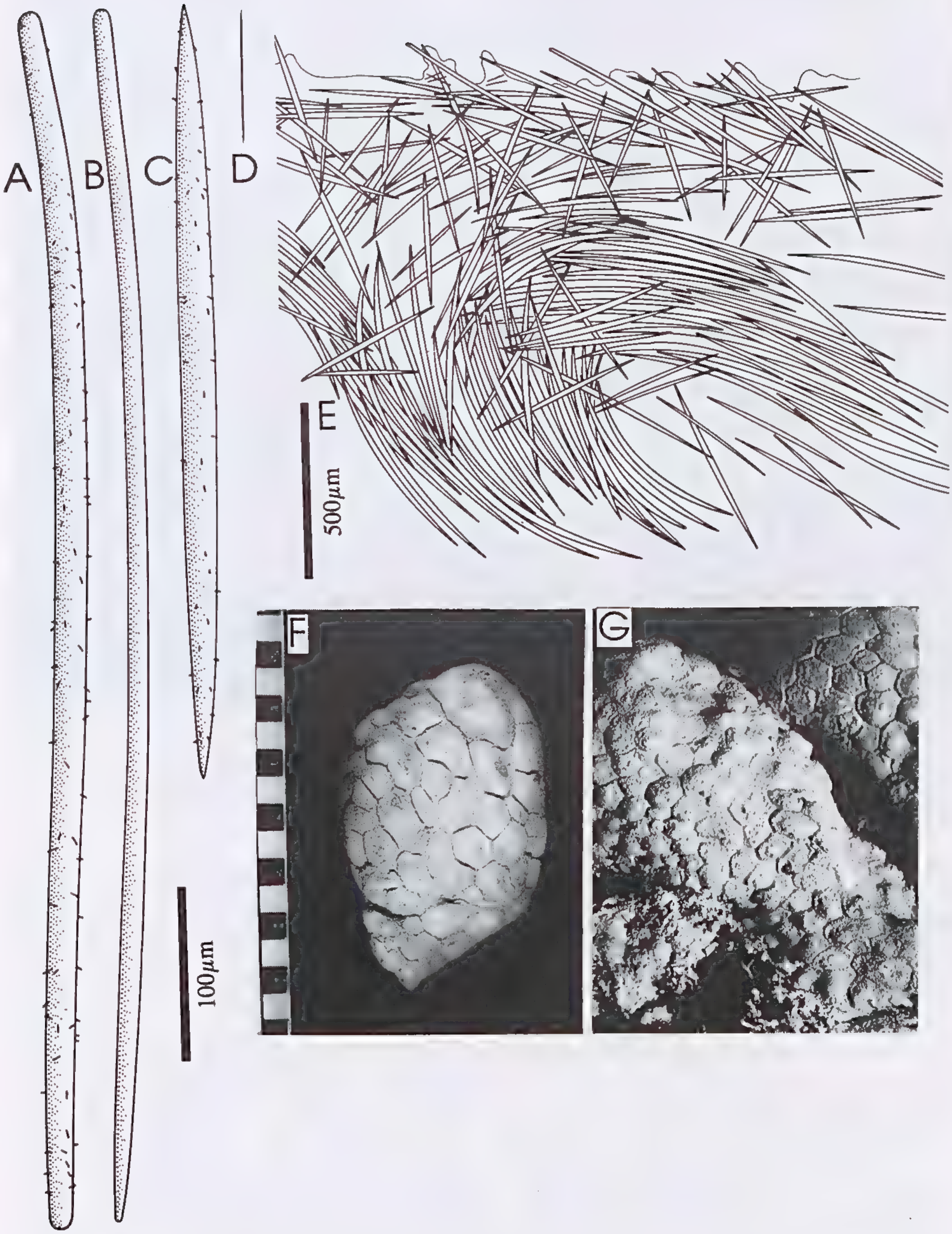

Fig. 3. *Myrmekioderma granulata* (Esper). **A,** microspined choanosomal strongyle; **B,** smooth choanosomal style; **C,** microspined ectosomal oxea; **D,** raphide microsclere; **E,** peripheral skeletal structure; **F,** preserved specimen NTM Z3249; **G,** live intertidal specimen NTM Z430.

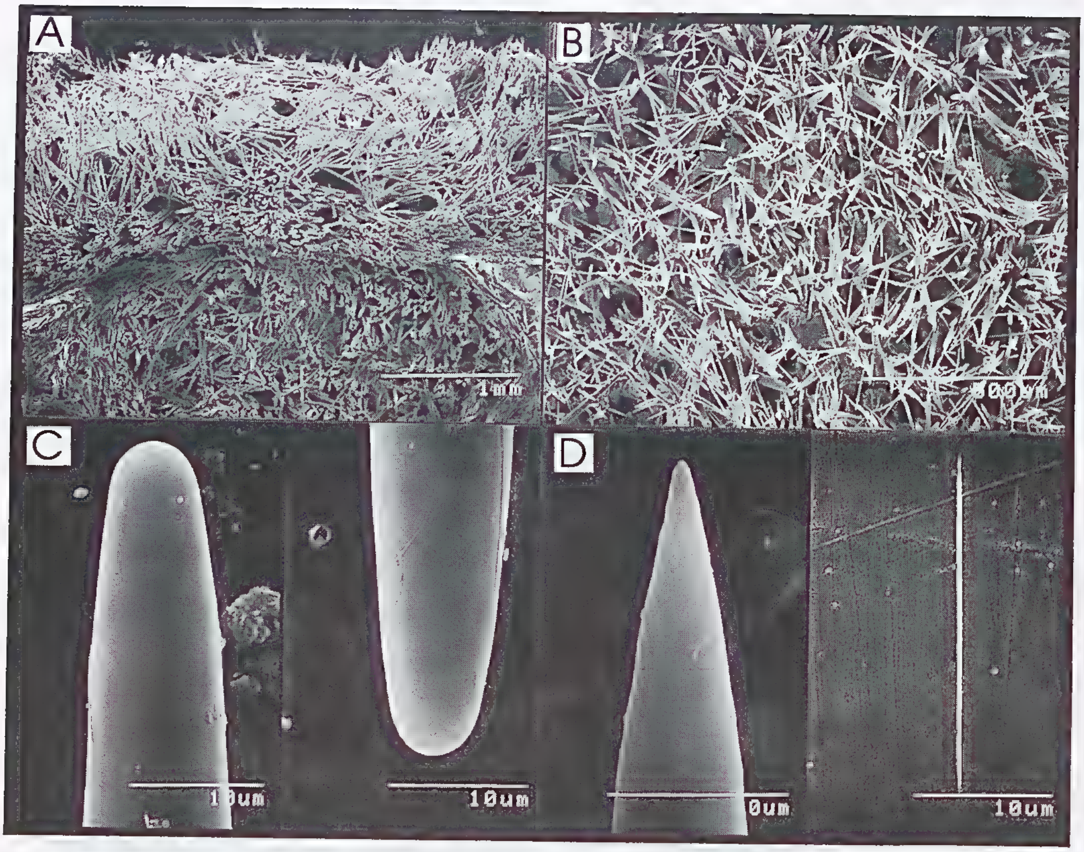

Fig. 4. *Myrmekioderma granulata* (Esper). Specimen NTM Z3249. **A,** perpendicular section through skeleton, showing compressed central portion of skeleton, oblique subectosomal spicule tracts and cavities, and paratangential ectosomal skeleton; **B,** transverse section of ectosomal skeleton showing outer surface of sponge with palisade of smaller ectosomal oxeas dispersed amongst larger choanosomal oxeas and styles; **C,** terminations of choanosomal strongyloxeas; **D,** termination of ectosomal oxea and raphide microsclere.

cies has not yet been discovered from the Great Barrier Reef, despite some intensive recent collections from many reefs, and it is possible that *M. granulata* is merely an incursive into the south Pacific region.

Populations of *M. granulata* in the central west-Pacific region have been frequently recorded (refer to records in de Laubenfels (1954) and Bergquist (1965)), whereas Australian and southern Pacific populations were only recently published (Hooper and Lévi 1993b; Hooper 1994). Nevertheless, its distribution within Australia is now relatively well understood, extending as far south as 27°S latitude on the eastern coast (restricted to inshore waters), and to 21.5°S latitude on the western coast of the continent, living in both coastal and offshore waters. Within the Beagle Gulf Marine Park this species has been seen on many shallow inshore fringing coral reefs and coral platforms, especially in the Darwin and Cobourg Peninsula regions (Hooper and Lévi 1993b), and it is also abundant on the more pristine oceanic coral reefs off the coast of northwest Australia (Hooper 1994) where it grows to a much larger size and ranges to greater depths than do the inshore populations.

Bergquist (1965) provided a detailed analysis of morphometric variability in *M. granulata*, which she correlated to some extent with regional populations of the species. Characters found to vary between populations included surface sculpturing, live colouration, geometry, spination and size of megascleres. These features are also shown to vary between the inshore northwest Australian populations and those from other localities. Specimens from the oceanic coral reefs of the Sahul Shelf and those from New Caledonia have meandering ridges excavating the apical surface (rather than discrete polygonal plates) (compare Hooper and Lévi 1993b: fig. 36A and the present work, Figure 3F-G); spicules are virtually entirely oxeote and smooth (whereas some inshore specimens have acanthose ectosomal oxeas and styloid modifications to choanosomal oxeas); and skeletal structure may be more cavernous (whereas most inshore samples appear to be more compact) (Hooper and Lévi 1993b and present study). It is possible that these differences are indicative of a sibling species relationship (rather than conspecificity), but this is not detectable solely on the basis of morphological data.

Genus *Topsentia* Berg

[*Anisoxya*] Topsent, 1898: 225 (junior homonym of *Anisoxya* Mulsant, (Coleoptera)).

Topsentia Berg, 1899: 77.

Trachyopsis Dendy, 1905: 147.

Oxeostilon Ferrer-Hernandez, 1922: 10.

Alloscleria Topsent, 1927: 6.

Coelocalypta Topsent, 1928: 167.

Laminospongia Pulitzer-Finali, 1983: 546.

Type species. *Anisoxya glabra* Topsent, 1898, by monotypy.

Diagnosis. Massive, amorphous or lobate growth forms, with brittle texture. Choanosomal skeleton completely lacking spongin, with mineral skeleton composed of oxeas in confused, directionless arrangement closely packed around aquiferous system, lacking any multispicular tracts. Subectosomal skeleton sometimes with subdermal cavities, but never large. Ectosomal skeleton with compact paratangential or erect layer of oxeas producing microhispid surface, typically without definite organisation but often closely compacted producing radial palisade. Megascleres oxeas in two or more size classes, including twisted, sinuous and contort modifications, usually without consistent size differences between ectosomal or choanosomal spicules.

Remarks. The genera *Topsentia*, *Epipolasis* and *Petromica* have completely confused halichondroid choanosomal skeletal structure, with spicules criss-crossing in deeper parts of the skeleton, they lack spongin within the choanosomal skeleton, and the only recognisable organisation is found at the surface in the form of spicule brushes. Species of *Topsentia* are most distinctive in the disorganisation of the choanosomal skeleton and lack of spongin (hence the brittle consistency), and they are typically drab in colour (Van Soest *et al.* 1990; Diaz *et al.* 1991). *Epipolasis* has a tangential felt-like ectosomal crust of smaller oxeas as well as raphide microscleres overlaying larger choanosomal oxeas, typically showing a strict localisation of spicule sizes, whereas in *Topsentia* there there may or may not be size difference between the ectosomal and choanosomal spicules, and if present it is usually not consistent (i.e. spicule size may not be exclusive to any particular region) (Diaz *et al.* 1991, 1993). Van Soest *et al.* (1990) include *Trachyopsis* in synonymy with *Topsentia*, but this only applies to the type species (others subsequently distributed amongst *Axinyssa* and *Spongosorites*). The genus is found in all tropical and subtropical oceans, extending from shallow waters to moderate depths. Within the Indo-Australian region eight species of *Topsentia* has been previously recorded: *T. solida* (Ridley and Dendy) with several junior synonyms (Hooper and Wiedenmayer 1994) from Tahiti, New Hebrides (Vanuatu), Christmas Island (Indian Ocean), Great Barrier Reef, and Ternate, Indonesia (Ridley and Dendy 1887; Keller 1891; Kirkpatrick 1900; Burton 1934), *T. glabrata* (Keller) from Ternate, Indonesia (Keller 1891), *T. indica* Hentschel from Aru Island, Indonesia (Hentschel 1912), *T. dura* (Lindgren) from Gaspar Straits, Java Sea, Indonesia (Lindgren 1897, 1898), *T. variabilis* (Lindgren) and *T. armata* (Lindgren) from Java, South China, southern Philippines and Arafura Seas (Lindgren 1897, 1898; Hentschel 1912; Wilson 1925); *T. cavernosa* (Topsent) from the Moluccas, Indonesia (Topsent 1897; Desqueyroux-Faundez 1981), and *T. halichondrioides* (Dendy) from the Gulf of Manaar, southern Philippines, northern Great Barrier Reef, New Zealand (Dendy 1905; Wilson 1925; Burton 1934; Bergquist 1970).

Topsentia halichondrioides (Dendy)
(Figs 5-6)

Trachyopsis halichondrioides Dendy, 1905: 147, pl.10, fig.10. - Burton 1926: 75, figs 6-7; - Burton 1934: 564; - Bergquist 1961: 185, fig.9; - Bergquist 1970: 34.

Type material. HOLOTYPE - BMNH 1907.2.1.44: Galle, Periya Paar, Gulf of Manaar, Ceylon (Sri Lanka).

Other Material. NTM Z3262: SW side of cliff face, Table Head, Port Essington, Cobourg Peninsula, NT, 11°13.5'S, 132°10.5'E, 5 m depth, 11 September 1986, coll. J.N.A. Hooper and C. Johnson, SCUBA. QM G303442: W side of Fish Reef, near wreck of HMAS *Brisbane*, Bynoe Harbour, NT, 12°26.1'S, 130°26.5'E, 11 m depth, 26 September 1993, coll. J.N.A. Hooper and L.J. Hobbs, SCUBA.

Distribution. Gulf of Manaar, Sri Lanka; southern Philippines; Chatham Rise, New Zealand; Pasco Reef, NE of Cooktown, Great Barrier Reef, Qld.; Fish Reef, Bynoe Harbour; Port Essington, Cobourg Peninsula, NT.

Habitat. Fringing coral reef slope; subtidal, 5-35 m depth.

Description. Thickly encrusting to massive-lobate, subspherical lumpy sponge, sometimes small volcano-shape (resembling small *Petrosia* or *Xestospongia*, Petrosiidae), up to 70 mm diameter. Oscules large, up to 5 mm diameter, discrete, apical, with raised collagenous lip.

Colour. Dark purple-mauve in life (Munsell 5RP 3/2), mauve-beige in air, white in ethanol.

Texture. Very firm, barely compressible texture; brittle, easily broken.

Surface. Opaque, optically smooth but minutely hispid.

Ectosomal skeleton. No detachable ectosomal layer. Larger oxeas protruding through surface forming an erect, continuous palisade of multispicular brushes, four or more spicules per brush; most larger spicules protruding only slightly beyond ectosomal collagenous layer, although protruding much further in preserved material. Smaller spicules more-or-less intermingled with larger brushes, also forming uni- or paucispicular tangential tracts, up to three spicules abreast, lying slightly sunken between protruding larger spicules.

Choanosomal skeleton. Dense halichondroid criss-cross reticulate mass of mainly larger oxeas, also with some smaller oxeas scattered between lacunae, without apparent organisation, but becoming vaguely ascending towards surface; subectosomal skeleton plumose (or plumo-reticulate), clearly differentiated from more disorganised halichondroid choanosomal skeleton; subectosomal spicules composed of mainly larger oxeas, forming bundles of 5-10 spicules, with smaller spicules also scattered between major bundles; subectosomal region slightly cavernous, lacunae up to 400 µm diameter, whereas deeper parts of choanosomal skeleton more closely reticulate. Spongin fibres present. Collagen very poorly developed in choanosomal mesohyl, slightly heavier in ectosomal region.

Spicules. Oxeas in two size classes: larger oxeas (predominantly choanosomal) moderately or slightly curved at centre, fusiform, with slightly telescoped points, less often sharply pointed (length 443-(562.3)-645 µm, width 18-(22.7)-28 µm); smaller oxeas (mostly ectosomal) straight or slightly curved, fusiform, sharply pointed (length 121-(185.5)-267 µm, width 5-(8.2)-9 µm).

Remarks. *Topsentia halichondrioides* is a distinctive subtidal halichondriid with purple-mauve colouration, bulbous growth form, optically smooth surface, and stony, brittle texture superficially resembling the stony demosponges (Petrosiidae). Its brittle, stony consistency reflects the low collagen and nil fibre content of the skeleton, which is completely dominated by a dense, disorganised reticulation of predominantly larger oxeas in the choanosome (only showing any semblance of organisation closer to the surface), and mostly smaller oxeas forming an erect, dense, continuous palisade at the surface. However, both sizes of oxeas also occur throughout the skeleton, suggesting that there is no strict localisation of spicule sizes, unlike *Epipolasis*. However, this distinction is one of grade and the value of this character is questionable.

Spicule dimensions, spicule geometry, skeletal structure and to some extent growth form in the northwest Australian population described above are closely comparable with the Gulf of Manaar population described by Dendy (1905). In contrast, specimens recorded from the Great Barrier Reef by Burton (1934) were not described, and their characteristics are still unknown.

Burton (1927) suggested that *T. halichondrioides* was a junior synonym of *T. solida* (Ridley and Dendy 1886), with several other of Keller's (1891) species from the Red Sea also included in synonymy (see Hooper and Wiedenmayer 1994: 213). The synonymy between *T. halichondrioides* and *T. solida* is refuted here, given that there are extensive differences between these nominal taxa in both their gross morphology, surface features, spicule geometry and spicule sizes (compare descriptions in Ridley and Dendy (1887: 4) and Dendy (1905: 147)), whereas Keller's (1891) material is still largely unknown and their affinities still require verification.

Comparisons with other species in this region are as follows: *T. solida* is grey in colour, has minute oscules, slightly compressible texture (i.e. not stony), lacks a well defined ectosomal palisade, and oxeas are strongylote rather than sharply pointed, up to 1100 x 38 µm

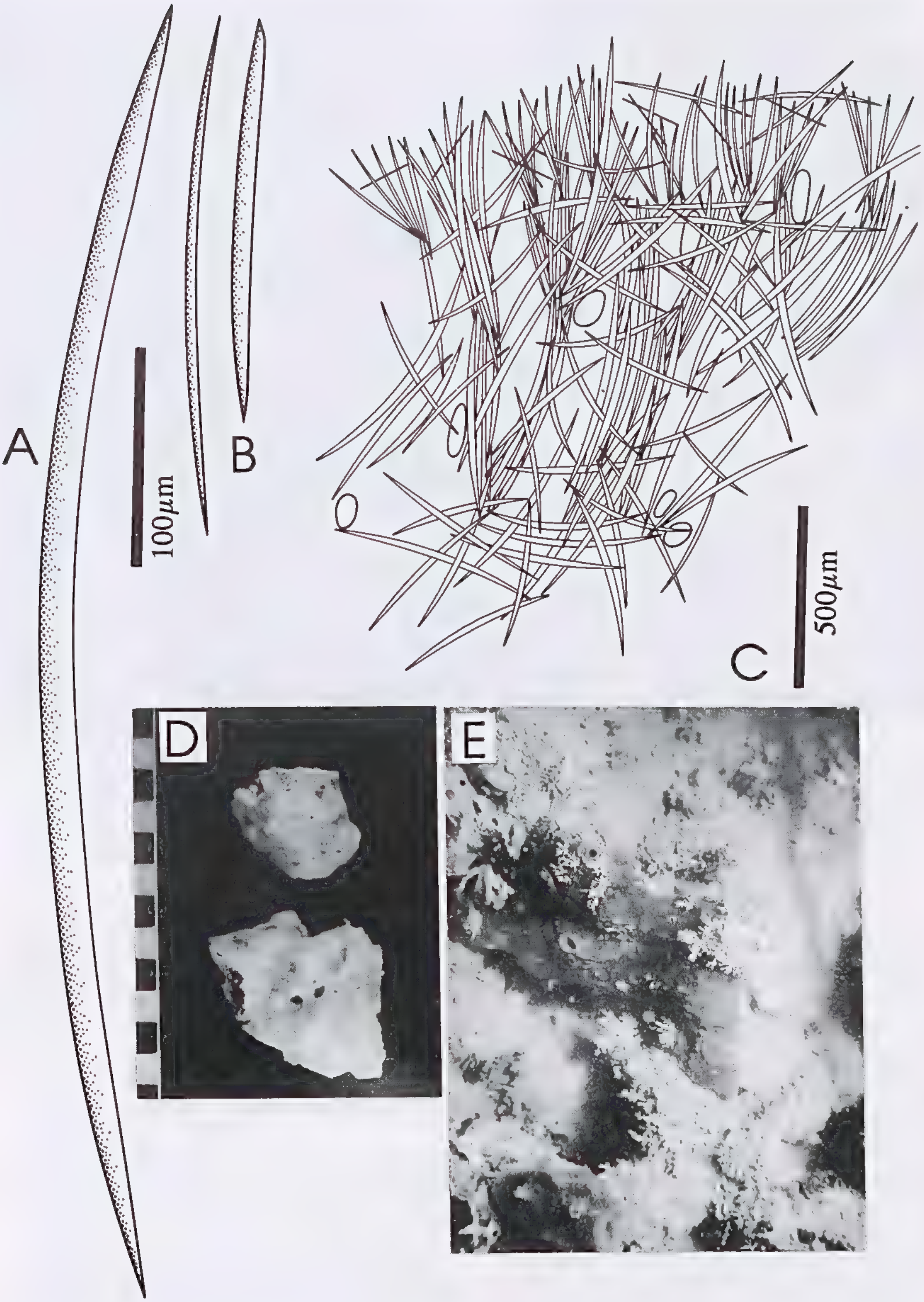

Fig. 5. *Topsentia halichondrioides* (Dendy). **A,** larger (predominantly) choanosomal oxea; **B,** smaller (predominantly) ectosomal oxeas; **C,** peripheral skeletal structure; **D,** preserved specimen QM G303442; **E,** live subtidal specimen QM G303442.

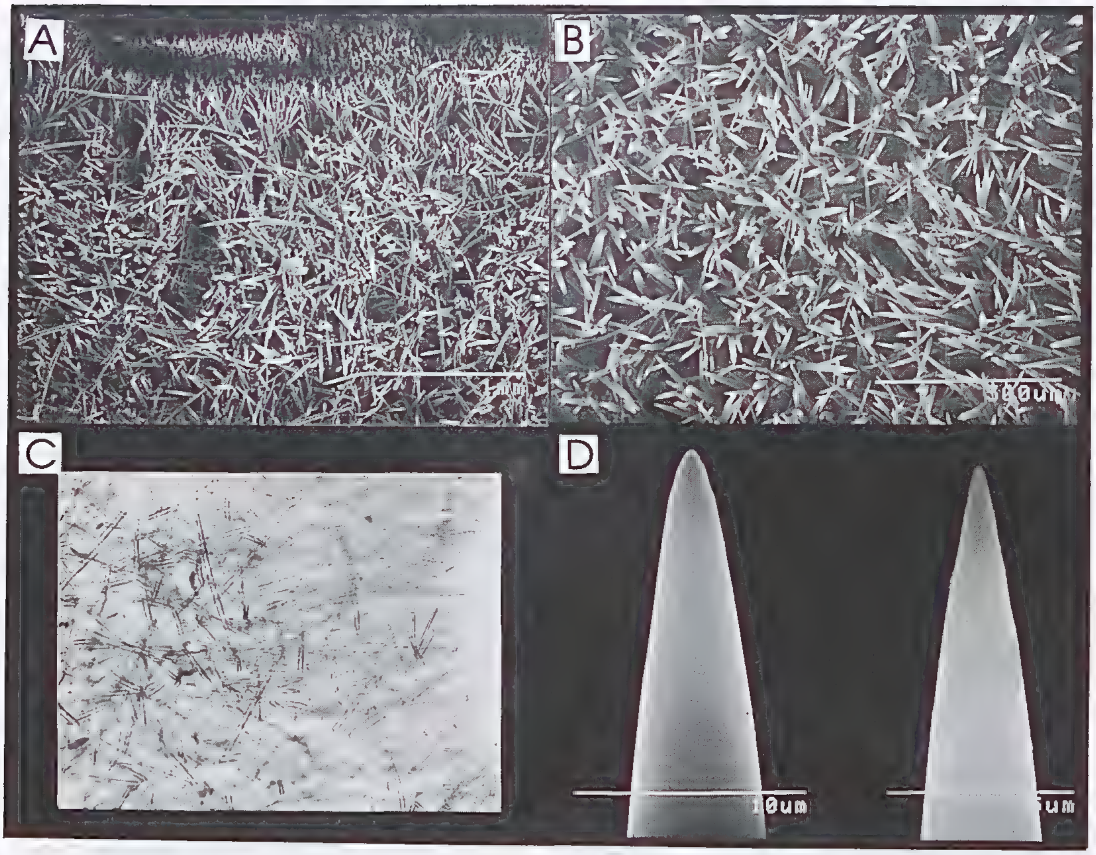

Fig. 6. *Topsentia halichondrioides* (Dendy). Specimen QM G303442. **A**, perpendicular section through skeleton showing disorganised ascending halichondroid choanosomal skeleton supporting the plumose subectosomal skeleton of larger oxeas, with a thin tangential ectosomal layer of smaller oxeas just below surface; **B**, transverse section of ectosomal skeleton showing outer surface of sponge with erect palisade of larger oxeas, with smaller oxeas lying below and tangential to this layer; **C**, light micrograph of section through peripheral skeleton showing distinct demarkation between the halichondroid reticulate choanosomal skeleton and the nearly plumose subectosomal skeleton; **D**, larger oxea (left) with faintly telescoped point, and sharply smaller oxea (right).

in dimensions; *T. dura* is greenish alive, olive-brown when preserved, stony consistency, small sunken oscules, two sizes of oxeas up to 600 x 20 µm and 260 x 6 µm, respectively, and an erect, continuous ectosomal palisade; *T. armata* is tuberculate, fibrous consistency, minute oscules, very large oxeas up to 1700 x 48 µm, and a sparse ectosomal skeleton; *T. variabilis* is massive flattened, grey-brown preserved, fibrous consistency, with prominent surface micro-conules, minute oscules, two sizes of oxeas, up to 770-1160 x 16-30 µm and 520-650 x 10-24 µm respectively, with an oblique, plumose ectosomal skeleton composed of discrete (not continuous) brushes, and multispicular tracts in the choanosomal skeleton; *T indica* is gray preserved, fibrous consistency, small oscules with slightly raised margins, oxeas in two sizes, up to 800 x 23-55 µm and 380 x 18 µm, respectively, ectosomal skeleton radial, well developed; *T. cavernosa* is massive, has a hard texture, moderately well developed erect ectosomal skeleton composed of only marginally smaller oxeas than in the choanosomal skeleton, and oxeas are 600-1000 x 17-20 µm.

Topsentia dura (Lindgren)
(Figs 7-8)

Halichondria dura Lindgren, 1897: 480. - Lindgren 1898: 286-287, pl. 17, fig. 2, pl. 19, fig. 3.

Type material. Fragment of holotype - BMNH 1929.11.26.41: Selat Kelasa (Gaspar Straits), Java Sea, Indonesia, coll. C. Aurivillius, 1891.

Other Material. NTM Z3195: East Point 'bommies', Darwin, NT, 12°24.5'S, 130°48.8'E, 9 m depth, 16 September 1987, coll. N. Smit,

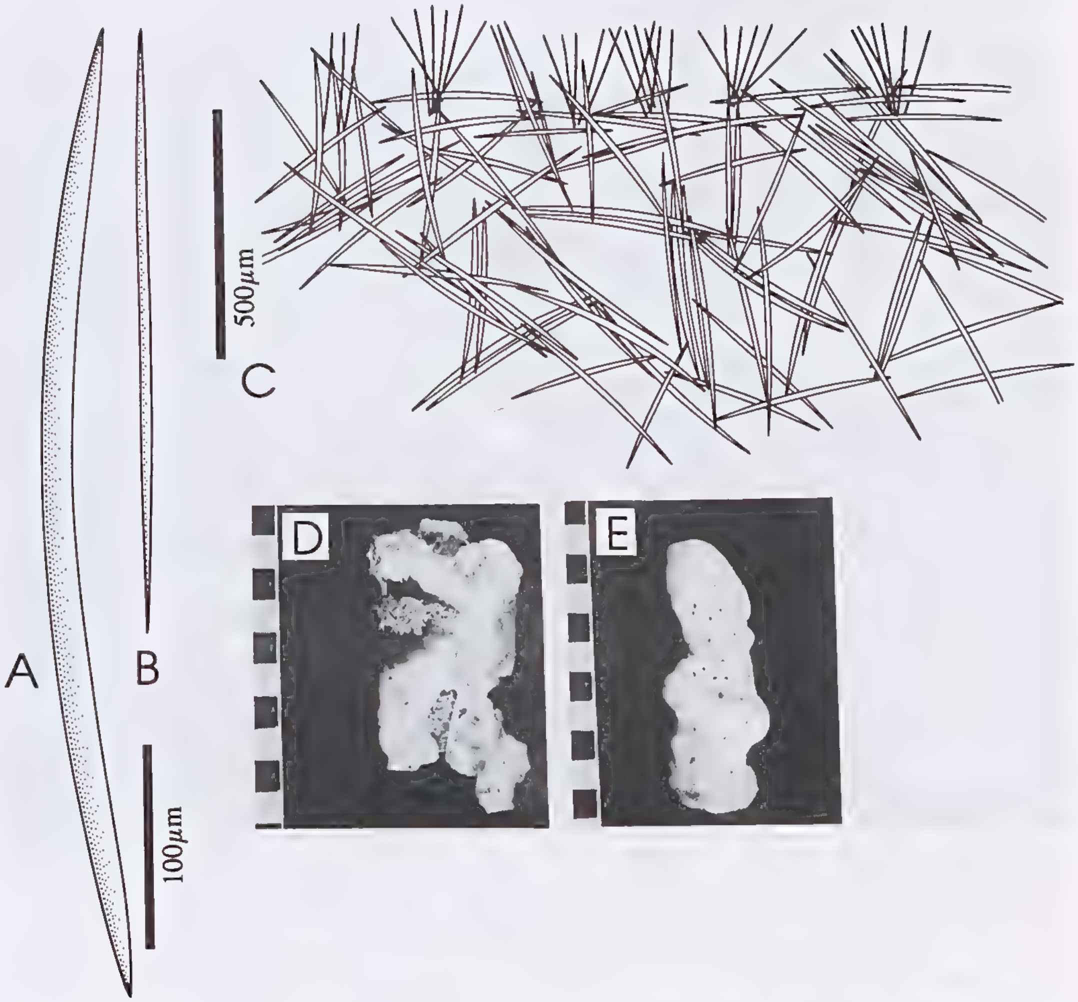

Fig. 7. *Topsentia dura* (Lindgren). **A,** larger (predominantly) choanosomal oxea; **B,** smaller (predominantly) ectosomal oxea; **C,** peripheral skeletal structure; **D,** preserved specimen NTM Z3195; **E,** specimen NTM Z1442.

SCUBA. NTM Z3178: Dudley Point Reef, East Point, Darwin, NT, 12°25.0'S, 130°49.1'E, 0.5 m depth, 10 September 1987, coll. N. Smit, by hand. NTM Z1442: Blue Hole, Gunn Point, NT, 12°09.0'S, 131°00.5'E, 25 m depth, 19 August 1983, coll. J.N.A. Hooper and P.N. Alderslade, SCUBA.

Distribution. Java Sea, Indonesia; East Point Aquatic Reserve and Gunn Point, Darwin Harbour, NT.

Habitat. Laterite rock and fringing coral reef, sandy substrate; intertidal-subtidal depths.

Description. Massive to lobate, irregularly anastamosing lobes, up to 110 mm long, 40 mm diameter. Oscules small, less than 2 mm diameter, discrete, scattered over surface of lobes, sunken in slight depressions on surface, without visible oscular rim.

Colour. Yellow-green to dark green in life (Munsell 5Y 8/4 - 2.5GY 5/4), white in ethanol.

Texture. Very firm, incompressible, brittle, easily broken.

Surface. Optically smooth but uneven, lumpy; encrusted in places with detritus; hispid.

Ectosomal skeleton. Continuous erect palisade of protruding single spicules or paucispicular brushes, composed mainly of larger oxeas, standing erect on ascending peripheral choanosomal tracts and protruding through surface only slightly beyond collagenous membrane; sparse tangential layer of smaller oxeas at base of protruding larger spicules, presumably lying on ectosomal membrane.

Choanosomal skeleton. Dense halichondroid disorganised mass of single spicules, mostly larger oxeas, organised only around lacunae

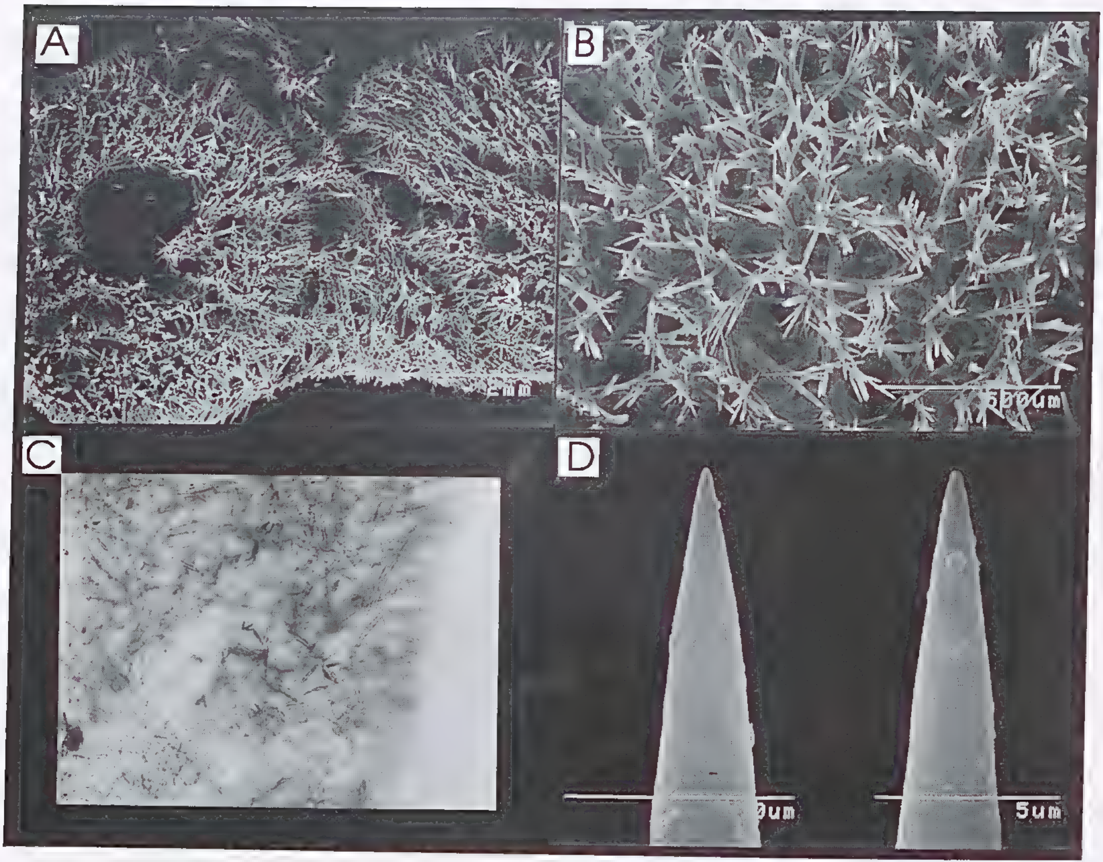

Fig. 8. *Topsentia dura* (Lindgren). Specimen NTM Z3195. **A,** perpendicular section through skeleton of branch showing halichondroid reticulate choanosome and plumose subectosomal skeletons; **B,** transverse section of ectosomal skeleton showing outer surface of sponge with a plumose ectosomal skeleton composed of protruding larger oxeas and a sparse tangential skeleton of smaller oxeas at their base; **C,** light micrograph of section through peripheral skeleton showing faint demarkation between the halichondroid reticulate choanosomal skeleton and the nearly plumose subectosomal skeleton; **D,** sharply pointed fusiform larger oxea (left) and smaller oxea (right).

and in peripheral skeleton, becoming plumose in periphery. Choanosomal and subectosomal regions equally cavernous, with occasionally large lacunae (>500 µm diameter) but mostly smaller oval meshes (<230 µm diameter). Only faint demarkation visible between choanosomal and subectosomal regions. Collagen in choanosome present but lightly pigmented.

Spicules. Oxeas in two sizes; larger predominantly choanosomal oxeas moderately or slightly curved at centre, fusiform, sharply pointed (length 344-(447.0)-585 µm, width 10-(12.3)-16 µm); smaller predominantly ectosomal oxeas straight or slightly curved, fusiform, sharply pointed (length 190-(211.5)-262 µm, width 1-(3.8)-6 µm)

Remarks. *Topsentia dura* is also characteristically stony in texture, has a massive lobate growth form, and has a well developed continuous palisade of erect ectosomal oxeas on the surface, similar to *T. halichondrioides*. It differs from *T. halichondrioides* in its live colouration (greenish), oscule morphology (small, sunken in slight depressions, without an oscular rim), spicule dimensions (mean of 447 x 12 µm and 211 x 4 µm for larger and smaller oxeas, respectively) (although only one size class of oxeas was originally recorded by Lindgren 1897, 1898), sharply pointed spicule terminations, and a less extensive ectosomal palisade. By comparison, *T. halichondrioides* has a distinctive purple-mauve live colouration, its oscules are large, discrete, lying on the apex of bulbous projections, with a membraneous lip, and oxeas differ in both dimensions (562 x 23 µm and 185 x 8 µm, respectively) and geometry (the larger ones commonly with telescoped points). Refer to Remarks for *T. halichondrioides* for further comparisons between species. As in *T. halichondrioides*, his species has some degree of localisation between spicule sizes forming various portions of the skeleton, with smaller oxeas predominantly found in the ectosome and larger oxeas predominantly in the choanosomal skeleton, reminiscent of *Epipolasis*. But this localisation is not completely strict, with both sizes also found throughout the skeleton, and the value of this character in *Topsentia* is questionable.

Genus *Ciocalypta* Bowerbank

Ciocalypta Bowerbank, 1863: 1105.

Leucophloeus Carter, 1883: 323.

Apatospongia Marshall, 1892: 16.

Type species. *Ciocalypta penicillus* Bowerbank, 1864, by monotypy.

Diagnosis. Growth form exclusively fistulose, with base burrowing into substrate. Surface usually semi-transparent, detachable, parchment-like. Choanosomal skeleton composed of styles in confused, directionless arrangement, spicule tracts unispicular, and spongin virtually absent in massive portion of sponge, whereas fistules supported by multispicular columns of styles confined to central portion of fistules. Ectosomal skeleton tangential layer of smaller styles, usually in bundles, supported by widely spaced multispicular tracts of styles, perpendicular to central choanosomal tracts, producing large subdermal cavities (lacunae) in peripheral region. Megascleres predominantly styles, sometimes accompanied by fewer oxeas.

Remarks. The revised concept of *Ciocalypta* is now restricted to fistulose species (Van Soest *et al.* 1990) which have exclusively stylote megascleres including a second, smaller category of ectosomal styles. Although fistulose growth forms seen in *Ciocalypta* are also known for some species of *Topsentia*, *Halichondria* and *Petromica* (i.e. this is likely to be an independently acquired ecological adaptation to living in sand substrates whereby fistules prevent smothering), these other genera differ from *Ciocalypta* substantially in their spicule geometry (oxeas instead of styles) and ectosomal characteristics (with erect bundles of spicules). *Ciocalypta* is most similar to *Amorphinopsis*, both having smaller ectosomal styles and larger stylote or oxeote choanosomal megascleres, whereas in *Ciocalypta* these ectosomal spicules are simply styles overlaying the choanosomal skeleton, in *Amorphinopsis* the ectosomal skeleton is composed of bundles of oxeas which are echinated by smaller styles. It is possible that these differences will eventually be considered artificial, especially considering that echinating ectosomal styles in *Amorphinopsis* can only be detected reliably using SEM techniques (i.e. a character of limited value to field biology), but any proposed merger between these genera requires more rigorous evaluation of a greater suite of species than presented here.

Species of *Ciocalypta* are widely distributed in temperate, subtropical and tropical oceans, mostly confined to shallow waters on muddy or sandy bottoms, frequently burrowing, at least partially, into the soft sediments. Within the Indo-Australian region eight species are known: *C. massalis* (Carter) from Bass Strait, Vic., and Fremantle, WA (Carter 1883); *C. polymastia* (Lendenfeld) from an unspecified locality, east coast of Australia (Lendenfeld 1888; Hallmann 1914); *C. occulata* (Kieschnick) and *C. simplex* Thiele from Ternate, Moluccas, Indonesia (Kieschnick 1896; Thiele 1900), and *C. subaceratus* (Ridley and Dendy) from southern Mindanao, Philippines, and Ternate, Indonesia (Ridley and Dendy 1886; Thiele 1900); *C. fenestrata* (Ridley) from the Arafura Sea, Great Barrier Reef, and South China Sea (Ridley 1884; Lindgren 1897, 1898; Burton 1934); *C. gracilis* (Hentschel) and *C. heterostyla* Hentschel from the Arafura Sea (Hentschel 1912), both synonymised in *Halichondria tyleri* (Bowerbank) by Burton (1959; see Hooper and Wiedenmayer 1994), but this synonymy is rejected.

Ciocalypta fenestrata (Ridley)

(Figs 9-10)

Leucophloeus fenestratus Ridley, 1884: 464, pl. 42, fig. s. - Burton, 1934: 564.

Leucophloeus fenestratus var. [unnamed] Ridley, 1884: 464, pl. 43, fig. g.

Not *Leucophloeus fenestratus* - Dendy, 1922: 124.

Hymeniacidon fenestratus - Lindgren, 1897: 483; - Lindgren, 1898: 312-313.

Axinyssa fenestratus - Van Soest *et al.*, 1990: 27; - Hooper and Bergquist, 1992: 102.

Type material. HOLOTYPE - BMNH 1882.2.23.255: Port Darwin, NT, 16-24 m depth, October 1881, HMS *Alert*, bottom mud and sand. Holotype of variety - BMNH 1882.2.23.195: Arafura Sea, NT, 64-72 m depth, 18 October 1881, coll. HMS *Alert*, bottom mud, sand, shells.

Other Material. NTM Z2018: West side Weed Reef, Darwin, NT, 12°29.2'S, 130°47.1'E,

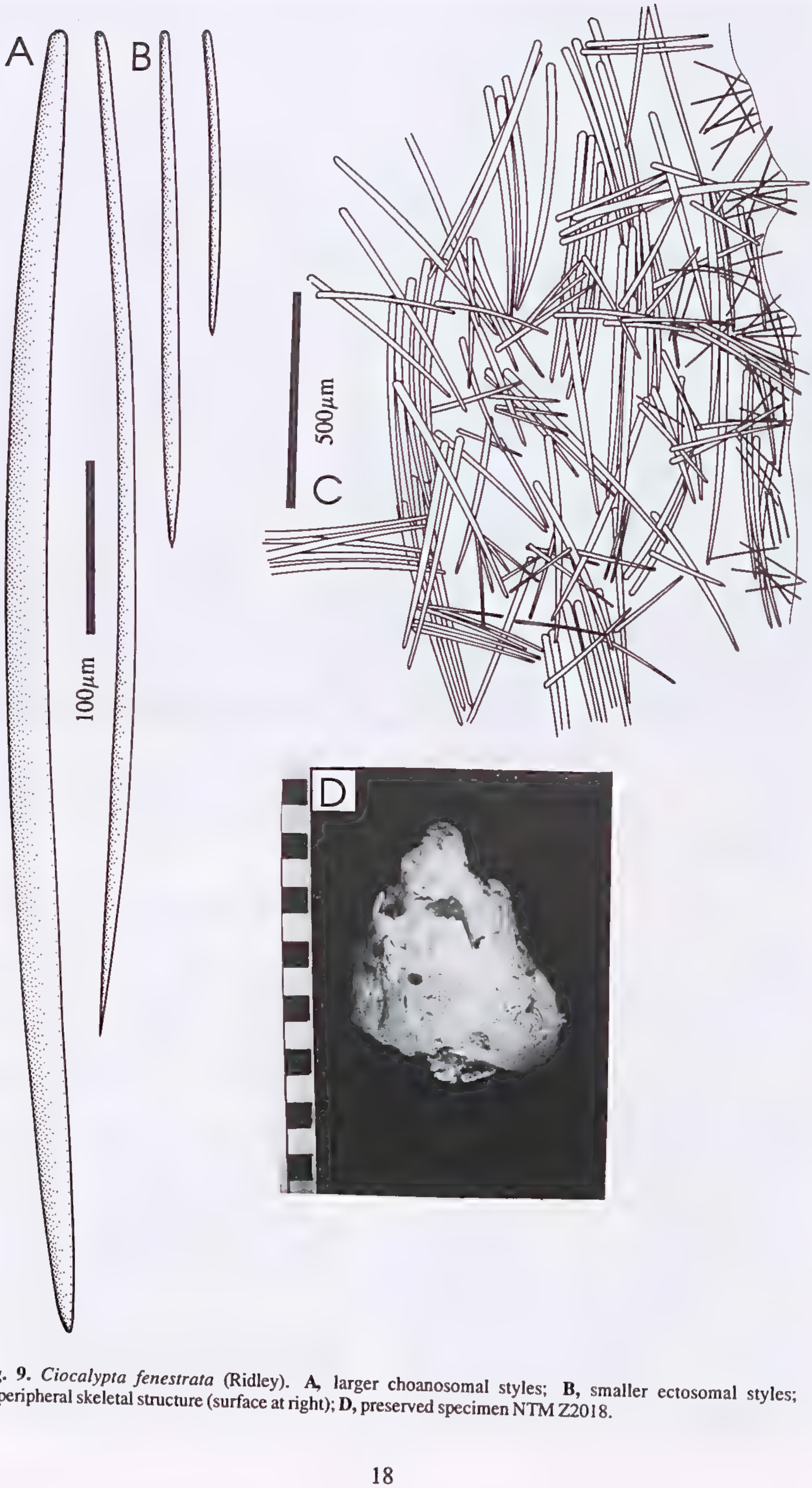

Fig. 9. *Ciocalypta fenestrata* (Ridley). **A,** larger choanosomal styles; **B,** smaller ectosomal styles; **C,** peripheral skeletal structure (surface at right); **D,** preserved specimen NTM Z2018.

8 m depth, 11 May 1984, coll. J.N.A. Hooper, P.J. Horner and P.N. Alderslade, SCUBA.

Distribution. Darwin Harbour, Arafura Sea, Shoal Bay, NT; Low Isles, Mangrove Park, Great Barrier Reef, Qld.; Providence Reef, Amirante, Indian Ocean; Java and Lesser Sunda Islands, Indonesia (Ridley 1884; Lindgren 1897, 1898; Dendy 1922).

Habitat. Burrowing in sand, mud, coral rubble, shell grit substrates; 4-72 m depth range.

Description. Partially burrowing; subspherical, massive, buttressed base (50mm diameter, 100 mm high), with small tapering fistules on apex (up to 30 mm long, 10 mm basal diameter) with basal portion buried beneath sediment and fistules protruding through sand. Oscules large, up to 8mm diameter, on apex of fistules.

Colour. Yellow-brown in life (Munsell 7.5YR 7/8), pale brown in ethanol.

Texture. Compressible, harsh, easily torn; sand and coral rubble embedded on under surface and outer surface of base.

Surface. Irregular, transparent and hispid.

Ectosomal skeleton. Multispicular tracts of larger choanosomal styles, up to three spicules abreast, lying tangential to surface, and irregular bundles of smaller ectosomal styles arranged mostly paratangentially to surface as plumose brushes. Collagen present but light in ectosomal region.

Choanosomal skeleton. In deeper regions of sponge, skeleton disorganised halichondroid criss-cross of both unispicular and multispicular tracts, containing 5-10 spicules abreast, composed of larger choanosomal styles; in subectosomal region tracts becoming more wide-meshed, paratangential, producing cavernous subectosomal region; in fistules choanosomal tracts more compressed in central region, cavernous towards

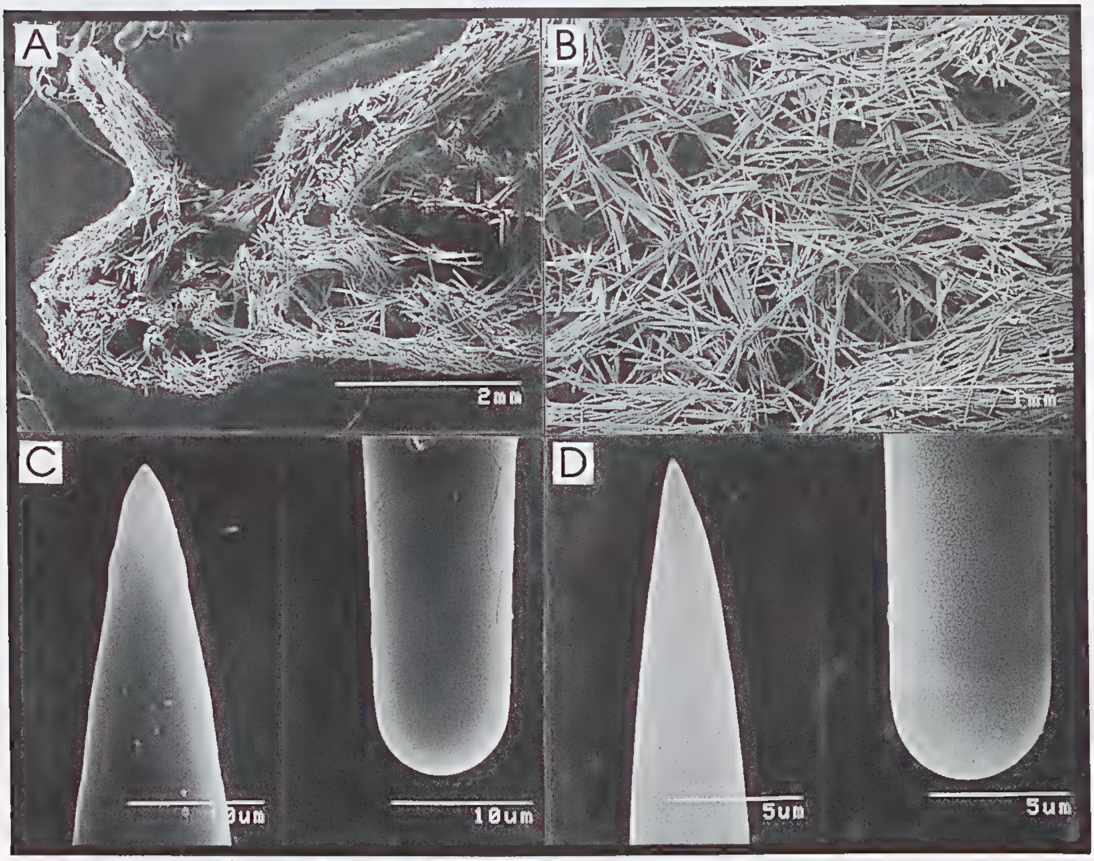

Fig. 10. *Ciocalypta fenestrata* (Ridley). Specimen NTM Z2018. **A,** perpendicular section through skeleton of fistule, showing multispicular halichondroid reticulate skeleton, large subectosomal lacunae, and paratangential subectosomal skeleton; **B,** transverse section of ectosomal skeleton showing outer surface of sponge with a tangential multispicular bundles of larger styles and paratangential bundles of smaller styles; **C,** terminations on choanosomal styles; **D,** terminations on ectosomal styles.

periphery; cavities at least as wide as spicule bundles, up to 400 µm in basal region, 1.5 mm in fistular region. Choanosomal spicule tracts predominantly composed of larger styles, whereas smaller (ectosomal) styles scattered throughout mesohyl. Collagen moderately abundant in central region of choanosome, sparse in peripheral skeleton; no spongin fibres observed.

Spicules. Larger choanosomal styles variable in size, straight or slightly curved at centre, fusiform with sharp points or very slightly telescoped points, tapering to hastate rounded base smaller in diameter than centre of spicule (length 355-(521.6)-775 µm, width 8-(19.2)-32 µm). Smaller ectosomal styles fusiform, sharply pointed with evenly rounded bases (length 153-(246.5)-330 µm, width 6-(9.1)-12 µm).

Remarks. Comparison between the known specimens of this species, including type material, confirm their conspecificity, and the species is referred here to *Ciocalypta* based on the possession of a specialised tangential-paratangential ectosomal skeleton. In re-evaluating the genera *Pseudaxinyssa* and *Axinyssa,* both Van Soest *et al.* (1990) and Hooper and Bergquist (1992) considered that this species might be included in *Axinyssa*, (based on its published skeletal structure and surface characters; the ectosomal skeleton of type material was in relatively poor condition). However, examination of fresh material described above discovered that smaller styles are mostly confined to a specialised ectosomal layer, not scattered within the choanosomal skeleton as presumed previously, indicating that *Ciocalypta* is a more appropriate generic assignment.

Ciocalypta fenestrata belongs to a species group of *Ciocalypta* characterised in having 'subacerate' larger choanosomal styles, whereby the thickest part of the spicule occurs in the apical third and the basal end is substantially narrower than the centre of the spicule. Included in this group are *C. oculata* (Kieschnick, 1896) from Ternate, Indonesia, *C. oculata* var. *maxima* Hentschel, 1912, from Aru Is, Indonesia, *C. subacerata* (Ridley and Dendy, 1886) from the Mindinao, Philippines, and Ternate, Indonesia, and *C. massalis* (Carter, 1883) from southwest Australia. The growth form of *C. subacerata* consists of massive anastomosing branches ('trabeculae') forming a cavernous construction, and megascleres are substantially larger than in *C. fenestrata* (1200 x 31 µm, 200 x 6 µm for both categories of styles). Spicule dimensions in *C. oculata* and its subspecies are also substantially larger (670-920 x 20-30 µm, 200-400 x 7-10 µm, respectively), and growth form consists of a thinner crust, but apparently not burrowing, with fairly large fistules up to 30 mm long and 15 mm diameter. Similarly, *C. massalis* is massive and buttressed, with a prominently rugose surface but apparently lacking fistules (probably destroyed in the unregistered BMNH dry type material, re-examined by the senior author in the BMNH 'Bowerbank Collection'). *Ciocalypta massalis* also has a relatively distinctive skeletal structure (consisting of a clearly differentiated compressed central region and radiating peripheral tracts of styles which become plumose closer to the surface, supporting a paratangential ectosomal crust composed of smaller styles), and spicule dimensions differ from those of *C. fenestrata* with only marginal size differences between the choanosomal and ectosomal styles (475 x 15 µm, 225 x 8 µm, respectively). It is possible that these four species are conspecific, representing substantial morphometric variability across a large latitudinal gradient, but this explanation is unacceptable under current interpretations of sponge morphometrics, and it is suggested that these species are at most close siblings.

Ciocalypta oscitans sp. nov.

(Figs 11-12)

Type material. HOLOTYPE - QM G303560: 4 km E of Fish Reef, Bynoe Harbour, NT, 12°24.8'S, 130°28.9'E, 17 m depth, 6 October 1993, coll. CCNT stn. 92 (ref. 1128), dredge.

Distribution. Bynoe Harbour, NT.

Habitat. Coarse sand and gravel sediment; subtidal.

Description. Massive, subspherical, 110 mm diameter, excavated, partially hollow interior, buttressed exterior, partially burrowing into soft sediments. Oscules very large (10-15 mm diameter) on upper surface, with vestigial fistules up to 10 mm long.

Colour. Pale mauve alive on deck (Munsell 5RP 8/2), white in ethanol.

Texture. Firm, compressible, harsh and easily torn.

Surface. Optically smooth, unornamented, with subectosomal cavities visible through translucent ectosomal membrane.

Ectosomal skeleton. Detachable, dense tangential layer, composed of both smaller and larger styles arranged mostly tangential to surface, in thick multispicular tracts, supported by

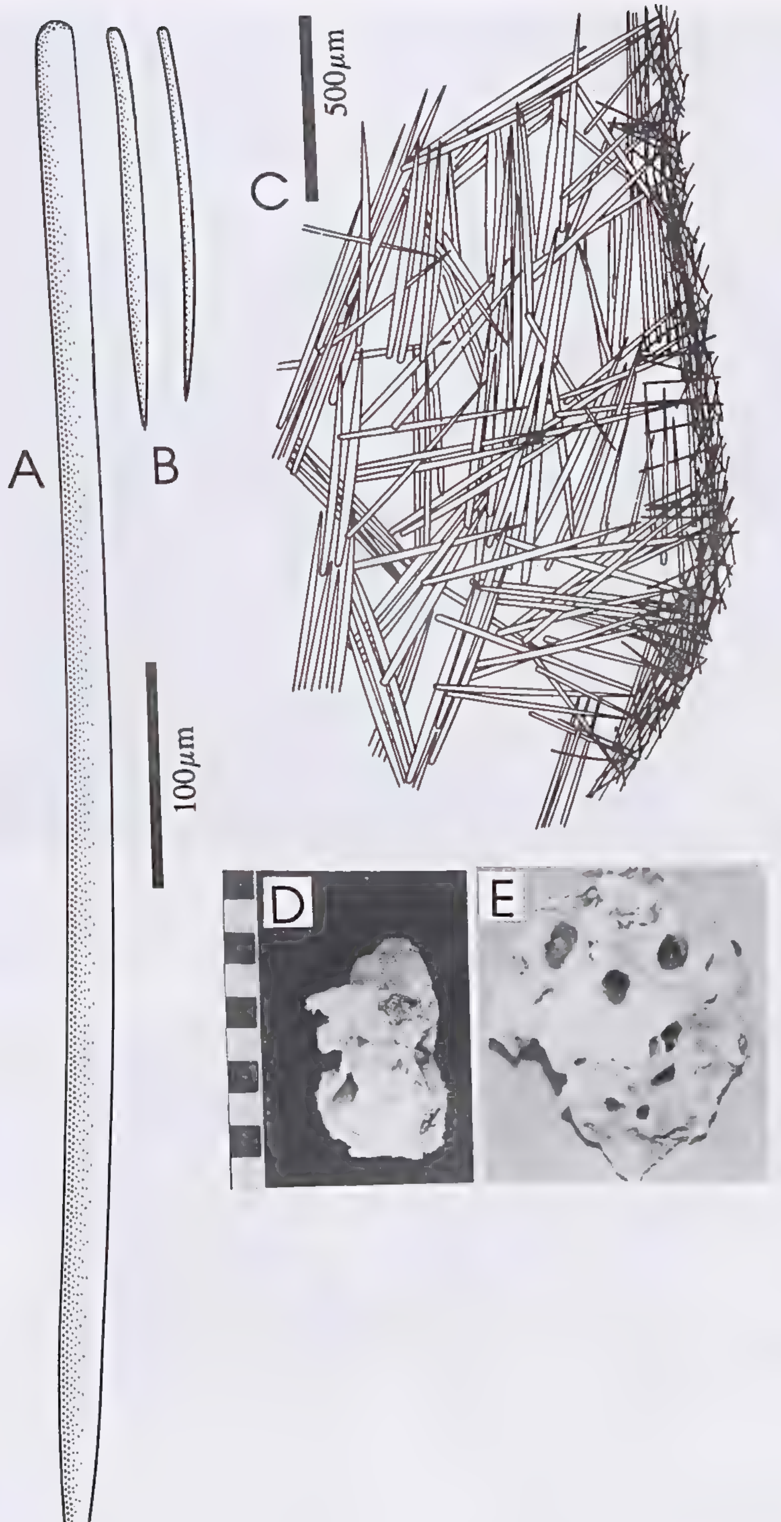

Fig. 11. *Ciocalypta oscitans* sp. nov. **A,** larger choanosomal style; **B,** smaller ectosomal styles; **C,** peripheral skeletal structure (surface at right); **D,** preserved holotype QM G303560; **E,** live holotype (on deck).

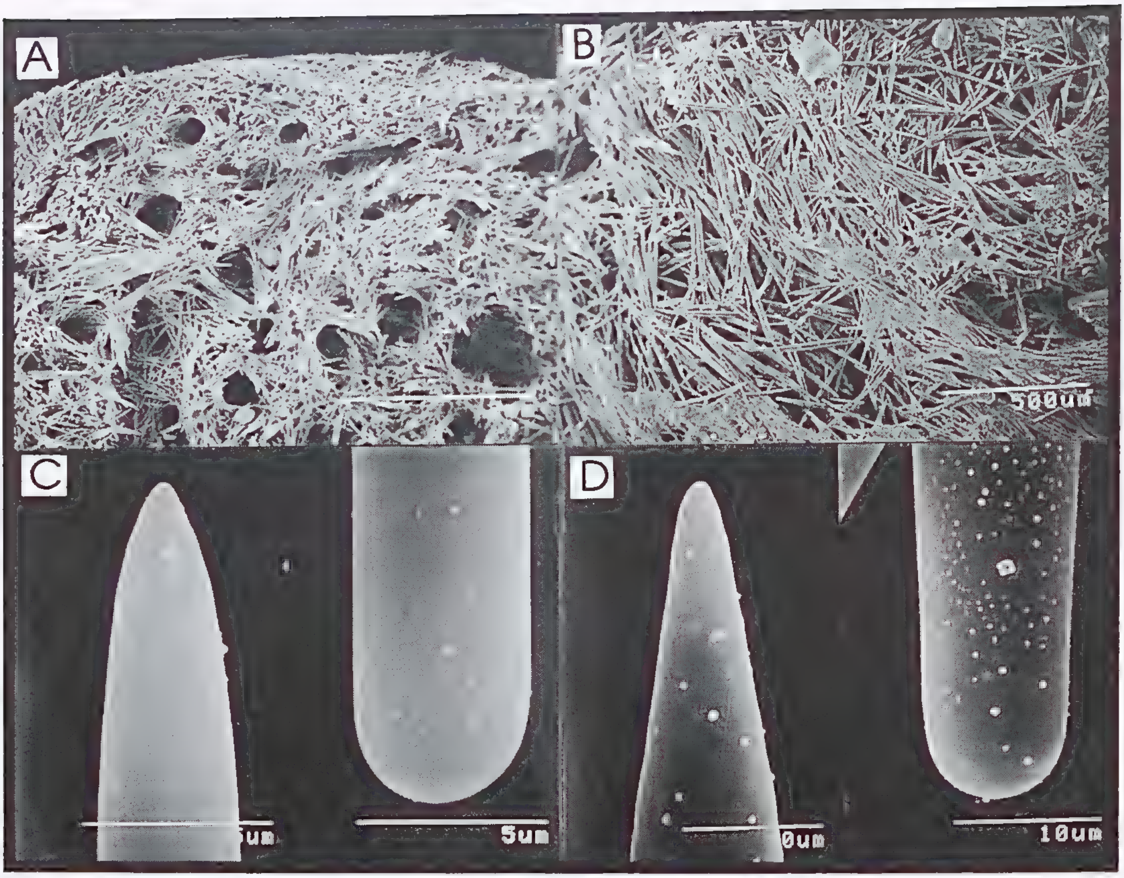

Fig. 12. *Ciocalypta oscitans* sp. nov. Holotype QM G303560. **A,** perpendicular section through skeleton showing disorganised halichondroid reticulation and cavernous meshes in central choanosomal region, more organised towards periphery; **B,** transverse section of ectosomal skeleton showing outer surface of sponge with a thin tangential layer of intermixed smaller and larger styles; **C,** hastate point (left) and rounded base of smaller ectosomal style (right); **D,** slightly telescoped point (left) and evenly rounded base of larger choanosomal style (right).

paratangential spicule tracts from subectosomal skeleton.

Choanosomal skeleton. Disorganised halichondroid reticulation of distinct multispicular tracts in centre of choanosome, composed mainly of larger choanosomal styles, with only slightly cavernous meshes throughout choanosomal and subectosomal regions, up to 500 µm diameter in choanosomal region but much smaller in peripheral skeleton; subectosomal tracts of larger styles ascending perpendicular to surface, producing nearly regular, open reticulate (criss-cross) arrangement of multispicular tracts, with large subdermal cavities visible close to surface; smaller styles also scattered throughout skeleton, mostly paratangential to major spicule tracts, these largely confined to ectosomal skeleton. Fibres absent; collagen poorly developed in mesohyl.

Spicules. Styles in two size classes: larger choanosomal styles straight or slightly curved near basal end, fusiform, sharply pointed or slightly telescoped points, with evenly rounded or slightly tapering hastate bases (length 515-(776.1)-944 µm, width 11-(16.7)-20 µm); smaller ectosomal styles hastate pointed, with evenly rounded bases (122-(175.4)-216 µm, width 5-(6.3)-8 µm).

Etymology. Named for the large oscules, from *oscitans* (L.), yawning.

Remarks. This species has a choanosomal skeleton notably more compact (less cavernous) than other known species of *Ciocalypta*. It also has a more dense tangential ectosomal skeleton, distinctly detachable from the subectosomal region, whereas in most other species the tangential layer of smaller ectosomal styles is relatively sparse and forms mainly uni- or paucispicular tracts. These characters are perhaps better developed than in most other species examined, but this is a subjective interpretation which is difficult to substantiate amongst the relatively homogeneous skeletal structures seen in this group of halichondriids (i.e. they are not particularly discriminatory between species). *Ciocalypta oscitans* is a typically 'amorphous' burrowing sponge, similar in growth form to many other halichondriids, such as *C. confossa* sp. nov., but it has distinctive, very large oscules raised on small (vestigial) fistules. Certainly in comparison with *C. confossa* the present species differs substantially in all skeletal structures, whereas spicule dimensions are comparable between the species (although spicule geometries are not). Spicule dimensions in both these burrowing species, *C. oscitans* and *C. confossa*, are also equivalent to those seen in *C. heterostyla* Hentschel, from Aru Island, Indonesia, although growth form is substantially different (the latter comprising erect fistulose ridges, distinct ectosomal 'skin' and oscules on the apex of ridges), and skeletal structures are markedly more cavernous in the Indonesian species.

Ciocalypta confossa sp. nov.
(Figs 13-14)

Type material. HOLOTYPE - NTM Z3106 (fragment NCI Q66C-0559-W): Parry Shoals, Arafura Sea, NT, 11°12.53'S, 129°42.08'E, 20 m depth, 15 August 1987, coll. A.M. Mussig and NCI AIMS, SCUBA.

Other Material. QM G303287: S of South Shell I., East Arm, Darwin, NT, 12°29.8'S, 130°53.5'E, intertidal, 19 September 1993, coll. J.N.A. Hooper and L.J. Hobbs, by hand. QM

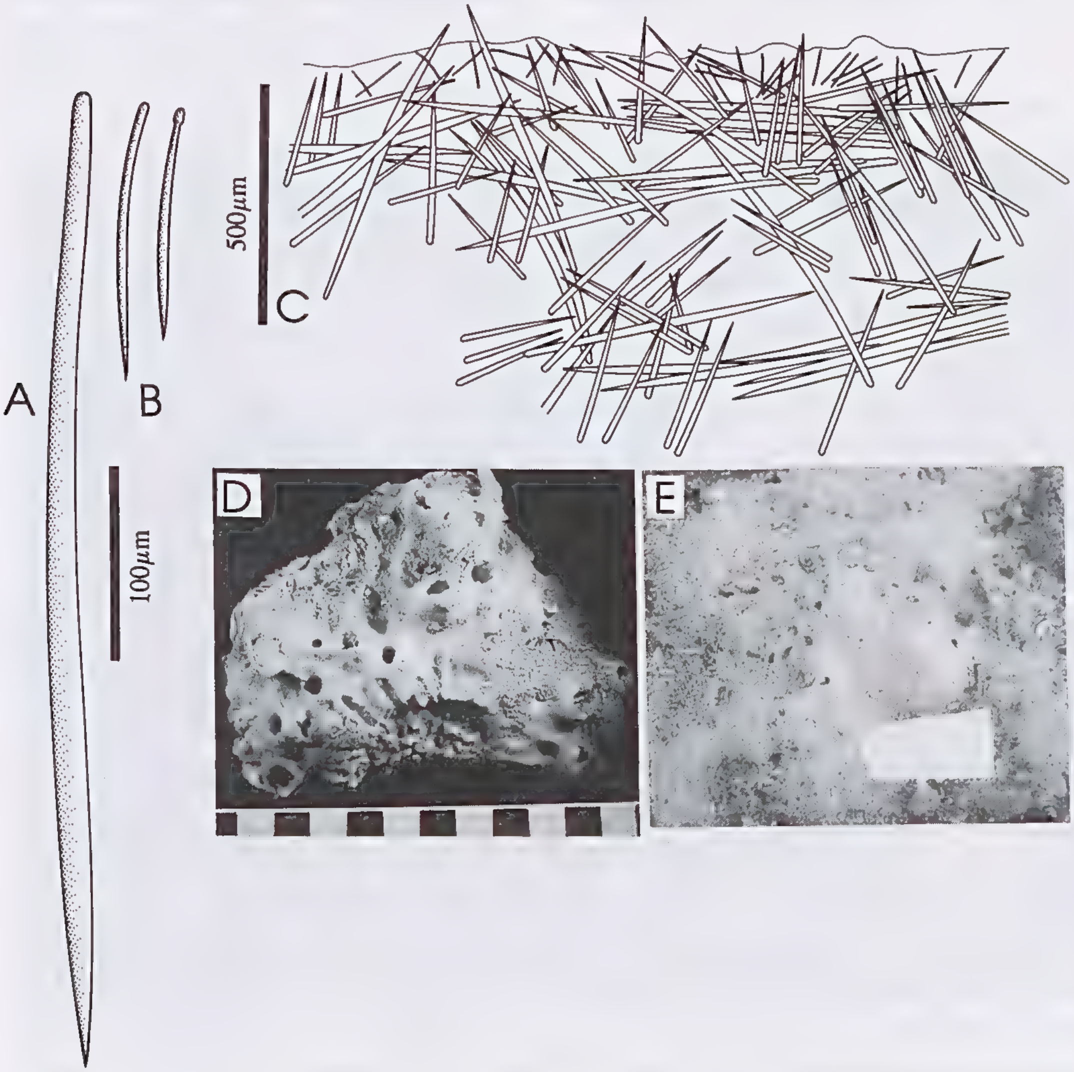

Fig. 13. *Ciocalypta confossa* sp. nov. **A,** larger choanosomal style; **B,** smaller ectosomal styles; **C,** peripheral skeletal structure; **D,** preserved specimen QM G303287; **E,** live intertidal specimen QM G303287, burrowing under substrate.

G303541: W of South West Vernon I., NT, 12°06.9'S, 131°04.8'E, 13 m depth, 10 October 1993, coll. CCNT stn. 140 (ref. 1664), dredge. QM G303558: NW of Cape Hotham, NT, 12°01.3'S, 131°13.9'E, 34 m depth, 9 October 1993, coll. CCNT stn. 159 (ref. 1498), dredge.

Distribution. East Arm, Darwin Harbour; Vernon Islands, Cape Hotham, Parry Shoals, Arafura Sea.

Habitat. Coral reef, rubble, coarse sand and shell grit; intertidal-subtidal depths.

Description. Completely burrowed into soft muddy substrate, with small fistules and small apical oscules barely visible above sediment; massive, up to 120 mm diameter, subspherical or tubulo-digitate, cavernous insubstantial construction (excavated throughout); fistules rudimentary, up to 18 mm long, 12 mm diameter, with moderately small oscules up to 5 mm diameter conspicuous on upper surface.

Colour. Yellow or yellow-brown in life (Munsell 2.5Y 8/8 - 7/10), pale brown in ethanol.

Texture. Firm, compressible, stringy, friable, easily torn.

Surface. Opaque, membranous, roughened, fibrous, usually with some detritus, often mud-covered *in situ*.

Ectosomal skeleton. Thin, detachable, tangential layer of small styles, scattered in uni- or paucispicular directionless tracts over surface, usually associated with granular collagen.

Choanosomal skeleton. Disorganised halichondroid reticulation of both multispicular directionless tracts and single spicules; multispicular tracts consisting of spicule bundles composed mainly of larger styles, 5-20 spicules abreast, without apparent organisation but forming vaguely halichondroid-reticulate skeleton; single spicules scattered throughout mesohyl in between major tracts; meshes large, oval, cavernous, up to 700 µm diameter, found throughout skeleton (not necessarily confined to subectosomal region). Fibres absent; poorly developed collagen in choanosomal mesohyl.

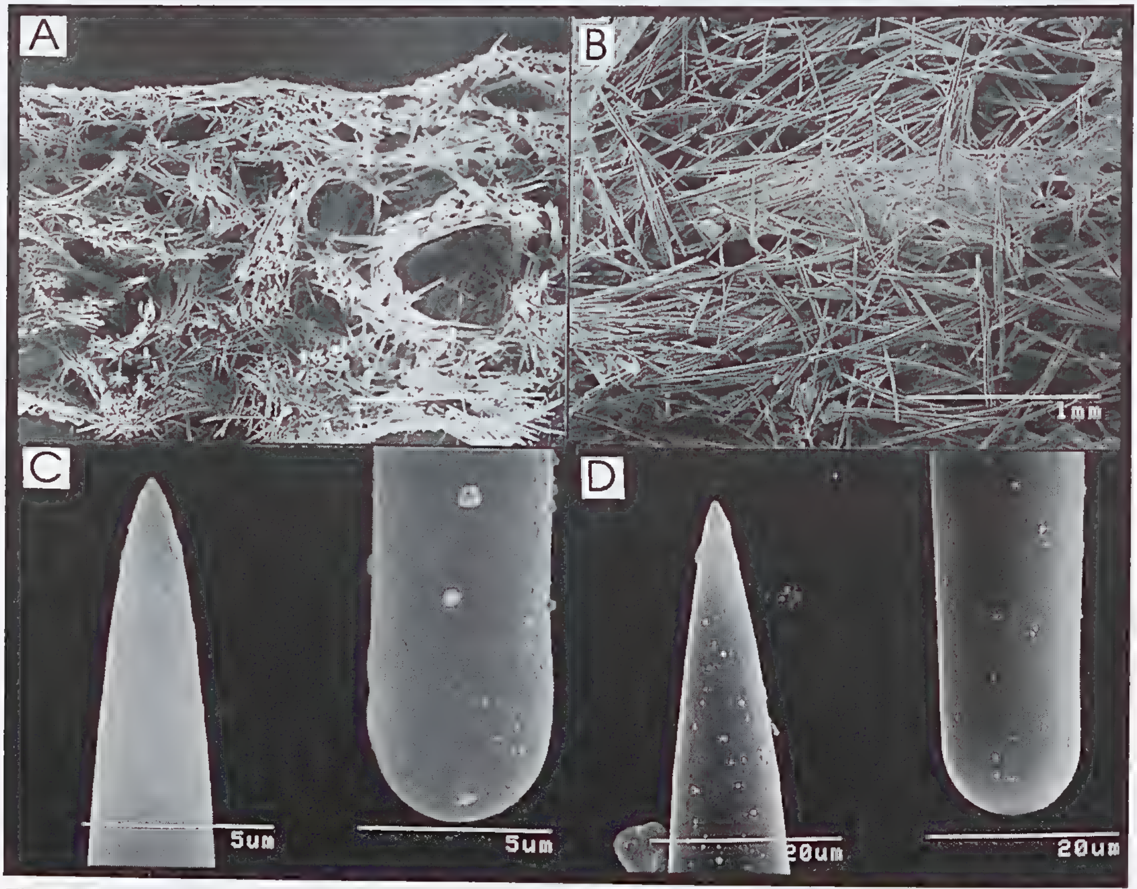

Fig. 14. *Ciocalypta confossa* sp. nov. Specimen QM G303287. **A,** perpendicular section through skeleton showing cavernous halichondroid reticulate skeleton supporting a thin ectosomal peel; **B,** transverse section of ectosomal skeleton showing outer surface of sponge with a thin tangential layer of smaller styles; **C,** smaller ectosomal style with fusiform point (left) and slightly subtylote base (right); **D,** larger choanosomal style with fusiform point (left) and evenly rounded base (right).

Spicules. Styles in two size classes; larger choanosomal styles straight or slightly curved near pointed end, fusiform, sharply pointed with evenly rounded bases or sometimes anisotylote (length 425-(661.6)-940 µm, width 8-(13.4)-20 µm); smaller ectosomal styles slightly curved at centre or near basal end, fusiform, sharply pointed, with evenly rounded or slightly subtylote bases, occasionally anisotylote or centrotylote (length 130-(183.3)-275 µm, width 3-(5.1)-7 µm).

Etymology. Named for the burrowing, excavated habit, from *confossus* (L.), perforated, full of holes.

Remarks. Although both are burrowing species, with vestigial fistules and similar ranges of spicule sizes, *C. confossa* differs from *C. oscitans* substantially in both its field characteristics and skeletal stuctures. It is nearly completely submerged below the substrate, with rudimentary fistules barely protruding above the surface, having much smaller oscules placed on top of these fistules, its ectosomal skeleton is sparse, with poorly developed paratangential single ectosomal styles scattered over the surface, overlaying a relatively cavernous subectosomal skeleton, spicule geometry of the smaller ectosomal styles in particular differs, and choanosomal skeletal structure is much less compact than in *C. oscitans*.

Genus *Amorphinopsis* Carter

Amorphinopsis Carter, 1887: 77.

Migas Sollas, 1908: 395 (junior homonym of *Migas* Koch (Arachnida)).

Prostylissa Topsent, 1925: 208.

Tumata de Laubenfels, 1936: 77.

Milne de Laubenfels, 1954: 116.

Type species. *Amorphinopsis excavans* Carter, 1887, by monotypy.

Diagnosis. Growth forms encrusting, excavating or ramose. Choanosomal skeleton with widely spaced halichondroid criss-cross of larger spicules, producing relatively large meshes bounded by mostly multispicular tracts. Ectosomal skeleton composed of thick bundles of larger oxeas lying tangential to surface echinated by smaller styles or oxeotes. Megascleres include smaller styles and/or oxeas, and larger choanosomal spicules predominantly oxeas or strongyloxeas, occasionally stylote.

Remarks. The possession of smaller styles forming the ectosomal skeleton, overlaying larger choanosomal megascleres, is shared with the sister genus *Ciocalypta*. In *Amorphinopsis*, however, these smaller styles echinate the tracts of larger choanosomal oxeas that lie tangential to the ectosome (which is unique amongst the Halichondriidae). The few known species appear to be restricted to the Indo-west Pacific region, confined to shallow waters (Van Soest *et al.* 1990).

Four species of *Amorphinopsis* have been previously described in the Indo-west Pacific: *A. excavans* (Carter) from Torres Strait, Java Sea and Arafura Sea (Lindgren 1897; Burton 1934), *A. megarrhaphea* (Lendenfeld) from the south coast of NSW (Lendenfeld 1888), *A. foetida* (Dendy) and *A. sacciformis* (Thiele) from the Moluccas, Indonesia, and Papua New Guinea (Topsent 1897; Thiele 1900; Kelly-Borges and Bergquist 1988).

Amorphinopsis excavans Carter
(Figs 15-16)

Amorphinopsis excavans Carter, 1887: 77, pl.5, figs 12-15. - Annandale 1915: 467, fig. 4A; - Burton 1959: 257; - Van Soest *et al.* 1990: 45, fig. 61.

Amorphinopsis excavans digitifera Annandale, 1915: 469, figs 4B, 5.

Halichondria armata Lindgren, 1897: 480. - Lindgren 1898: 285-286, pl. 17, fig. 1, pl. 19, fig. 2.

Halichondria panicea hemisphaerica Dendy, 1905: 146-147.

Amorphinopsis kempi Kumar, 1925: 226, fig. 7.

Prostylissa siamensis Topsent, 1925: 208, figs 1-2. - Van Soest *et al.* 1990: 45, fig. 64.

Type material. HOLOTYPE - IM 6597/7 ZEV: Mergui Archipelago, Burma, Andaman Sea. holotype fragment of *H. armata* - BMNH 1929.11.26.31 (slide): Batan Island, Philippines. Syntype of *H. panicea hemisphaerica* - BMNH 1907.2.1.43: N. of Galle, Gulf of Manaar, Sri Lanka. Holotype of *A. excavans digitifera* - IM 501/7 ZEV: Fisher Bay, Tavoy Island, off Tenasserim, Burma, Andaman Sea. Holotype of *A. kempi* - IM P199/1: Waltair, Bay of Bengal, India.

Other Material. QM G303658: Vernon Islands, South of Marsh Shoals, NT, 12°07.0'S, 130°56.1'E, 16 m depth, 11 October 1993, coll. CCNT stn. 138, dredge (ref. CCNT 1997).

Distribution. Widespread in coral reefs of the Indo-west Pacific - Gulf of Manaar, Sri Lanka; Bay of Bengal, India; Andaman Sea,

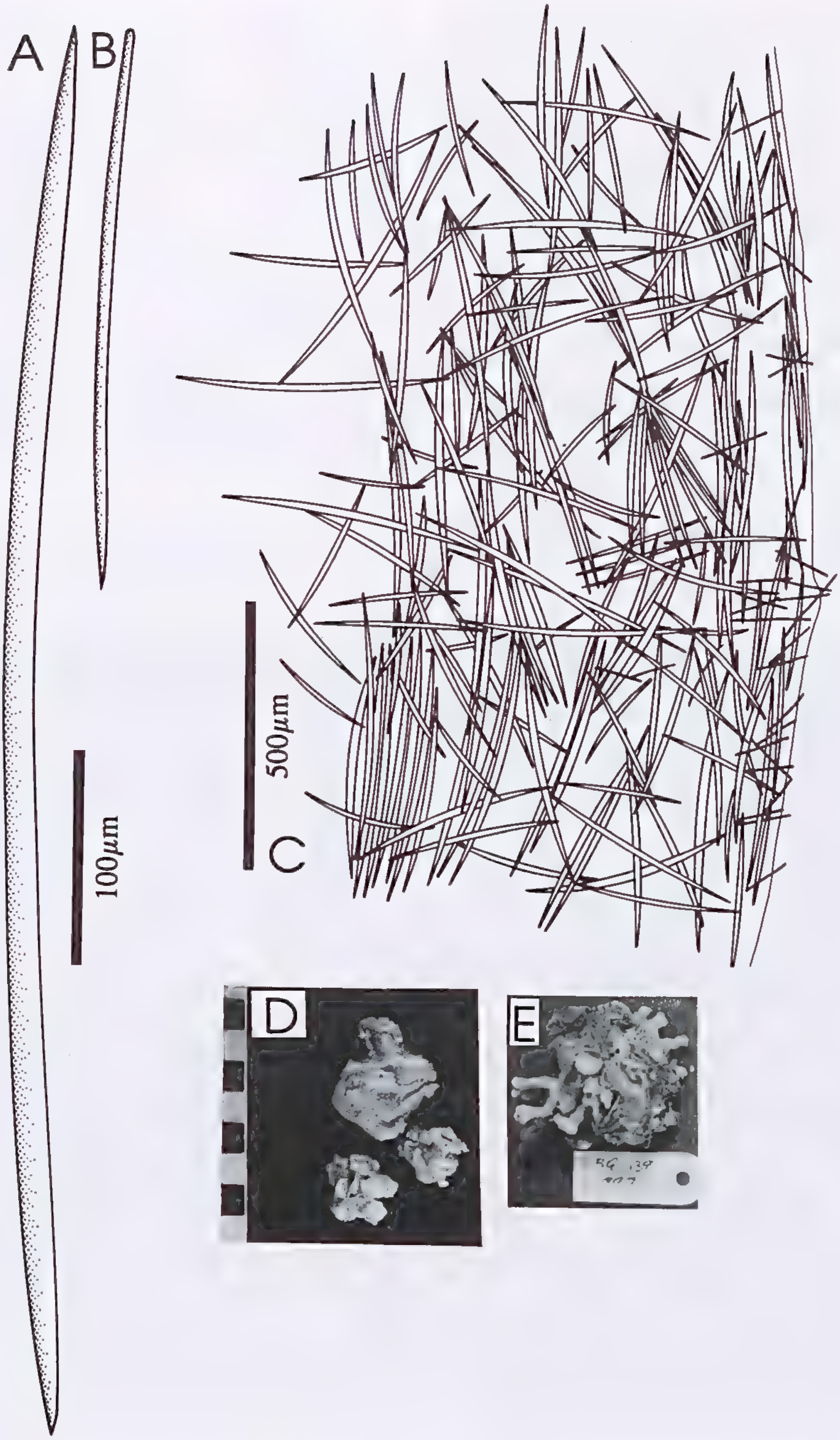

Fig. 15. *Amorphinopsis excavans* Carter. **A,** larger choanosomal oxea; **B,** smaller ectosomal style; **C,** peripheral skeletal structure (surface at right); **D,** preserved specimen QM G303658; **E,** live specimen (on deck) encrusting coral.

Burma; South China Sea, Vietnam; Sulu Sea, Philippines; Gaspar Strait, Java Sea, Banda Sea and Arafura Sea, Indonesia; Vernon Islands, NT; Torres Strait, Qld.

Habitat. Gravel substrate; intertidal to 54 m depth.

Description. Thickly encrusting over *Pocillopora* coral fronds and large fragments of siliceous detritus, up to 15 mm thick, with convoluted surface profile. Oscules small, discrete, 1-2 mm diameter, scattered over surface, with slighlty raised membraneous lip.

Colour. Yellow-brown in life (Munsell 7.5YR 7/10), beige-white in ethanol.

Texture. Firm but compressible, easily torn.

Surface. Opaque, optically smooth, porous convoluted surface.

Ectosomal skeleton. Ectosome a thin peel, detachable, composed of tangential layer of larger oxeas, mostly in bundles lying on surface, with small styles oriented paratangential to ("echinating") and protruding through surface. Ectosome with sparse collagen and detritus.

Choanosomal skeleton. Tightly packed confused halichondroid reticulate skeleton of larger oxeote spicules, mostly formed by multispicular bundles bound together with very little collagenous material, producing small elongate cavities (lacunae) and oval meshes throughout skeleton. Towards periphery, spicule tracts becoming more paratangential, subplumose, producing larger lacunae free of spicules. Sparse collagen dispersed throughout mesohyl.

Spicules. Larger choanosomal oxeas fusiform, slightly curved at centre, tapering to sharp points (length 175-(506.6)-642 µm, width 8-(12.8)-18 µm). Smaller ectosomal styles slightly curved at

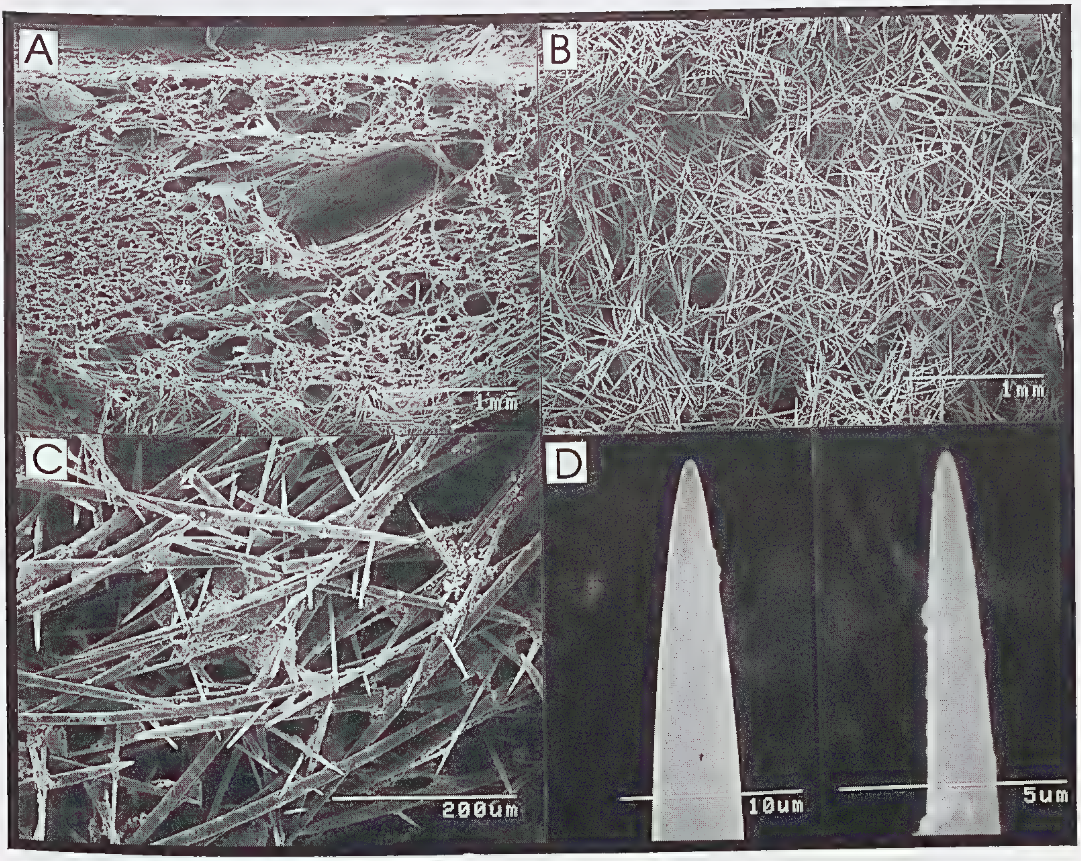

Fig. 16. *Amorphinopsis excavans* Carter. Specimen QM G303658. **A,** perpendicular section through skeleton, showing halichondroid reticulate skeleton of mostly multispicular tracts and spaces (lacunae) within choansomal skeleton, paratangential subplumose subectosomal tracts and thin ectosomal peel; **B,** transverse section of ectosomal skeleton showing outer surface of sponge with a tangential layer of larger oxeas, in bundles, echinated by small styles; **C,** closer view of tangential ectosomal skeleton; **D,** sharply pointed terminations on choanosomal oxeas (left) and ectosomal styles (right).

centre, with rounded bases and tapering fusiform points (length 164-(190.3)-244 µm, width 2-(4.1)-8 µm).

Remarks. *Amorphinopsis excavans* is a widely distributed Indo-west Pacific species commonly associated with coral reefs and coral rubble. Burton (1959) included it under the name *A. megalorhaphis* (Carter), but this synonymy cannot be corroborated (the type material being lost; Hooper and Wiedenmayer 1994) and the name '*excavans*' has seniority. Similarly, many of the synonyms given by Burton (1959) are questionable, and we include only those species for which conspecificity has been established through comparison of relevant type material (listed above). In particular, two species mentioned in synonymy with *A. excavans*, *Halichondria dura* Lindgren and *H. variabilis* Lindgren (both from Indonesia and both belonging to *Topsentia*), are specifically excluded from comparison of fragments of type material (BMNH 1929.11.26.41 and BMNH 1929.11.26.1, respectively). Significant differences in spicule sizes, geometries and skeletal structures justify their separation contrary to the opinion of Burton (1959), and followed subsequently by Hooper and Wiedenmayer (1994). *Amorphinopsis excavans* is most closely related to *A. foetida* in skeletal structure (both species having relatively cavernous choanosomal skeletons), differing from the latter species in spicule geometry and spicule dimensions.

The specimen described above from the Vernon Islands is a typical example of this widely dispersed species, showing close similarities to the type material in its excavating growth form, and ectosomal and choanosomal skeletal structure (tangential 'echinating' smaller styles; relatively wide-meshed choanosomal halichondroid reticulation, respectively). Conversely, it is atypical in having relatively consistent spicule geometry (most recorded populations of *A. excavans* have interchangeable smaller oxeas and styles composing the tangential ectosomal skeleton) and in the specific dimensions of spicules (these are relatively smaller than most described specimens). Nevertheless, present material clearly belongs to this species.

Amorphinopsis foetida (Dendy)

(Figs 17-18)

Hymeniacidon (?) foetida Dendy, 1889: 87-88, pl . 4 fig. 5.

Amorphinopsis foetida - Topsent, 1897: 445, pl. 18, fig. 8; - Desqueyroux-Faundez 1981: 757.

Ciocalypta foetida - Lindgren, 1897: 483; - Lindgren 1898: 313-314; - Thiele 1900: 75, pl. 3 fig. 26; - Hentschel 1912: 427-428.

Leucophloeus foetida - Dendy, 1905: 197, 234.

Material. QMG303677: Shoal Bay, middle of bay, NT, 12°13.1'S, 130°56.0'E, 17 m depth, 12 October 1993, coll. CCNT stn. 122, dredge (ref. CCNT 2104).

Distribution. Tuticorin, Gulf of Manaar, Sri Lanka; S. coast of Vietnam, South China Sea; Ambon and Ternate, Moluccas, Indonesia; Arafura Sea, Indonesia; Shoal Bay, Darwin region, NT.

Habitat. Sandy mud substrate with sparse seagrass cover.

Description. Enlarged base burrowing into substrate with two subconical, low volcano-shaped fistules protruding above sediment. Larger oscules, up to 8 mm diameter, grouped on a terminal sieve-plate at the apex of each fistule.

Colour. Yellow-beige on deck (Munsell 7.5YR 8/2), white in ethanol.

Texture. Soft, compressible and easily torn.

Surface. Transparent, membranous, irregular, wrinkled and hispid.

Ectosomal skeleton. Dense layer of larger choanosomal styles lying tangential to the surface, mostly in irregular multispicular bundles of 2-10 spicules, with smaller ectosomal styles producing tufts ('echinating') around spicule bundles. Spicule bundles bound together with small amounts of collagen.

Choanosomal skeleton. Architecture cavernous, reticulate, with distinct structural differences between central and peripheral skeletons. Deeper choanosomal skeleton with large multispicular tracts composed of larger choanosomal styles, 20-50 spicules wide, mainly confined to central region of sponge (particularly in fistules). Peripheral skeleton with widely spaced multispicular radial tracts of styles arising perpendicular to central skeleton, becoming plumose in near surface, supporting tangential ectosomal skeleton; spicule tracts forming wide-meshed reticulate skeleton with very large cavernous meshes up to 2 mm diameter, particularly in fistular region; some collagenous material associated with spicule tracts but true fibres absent.

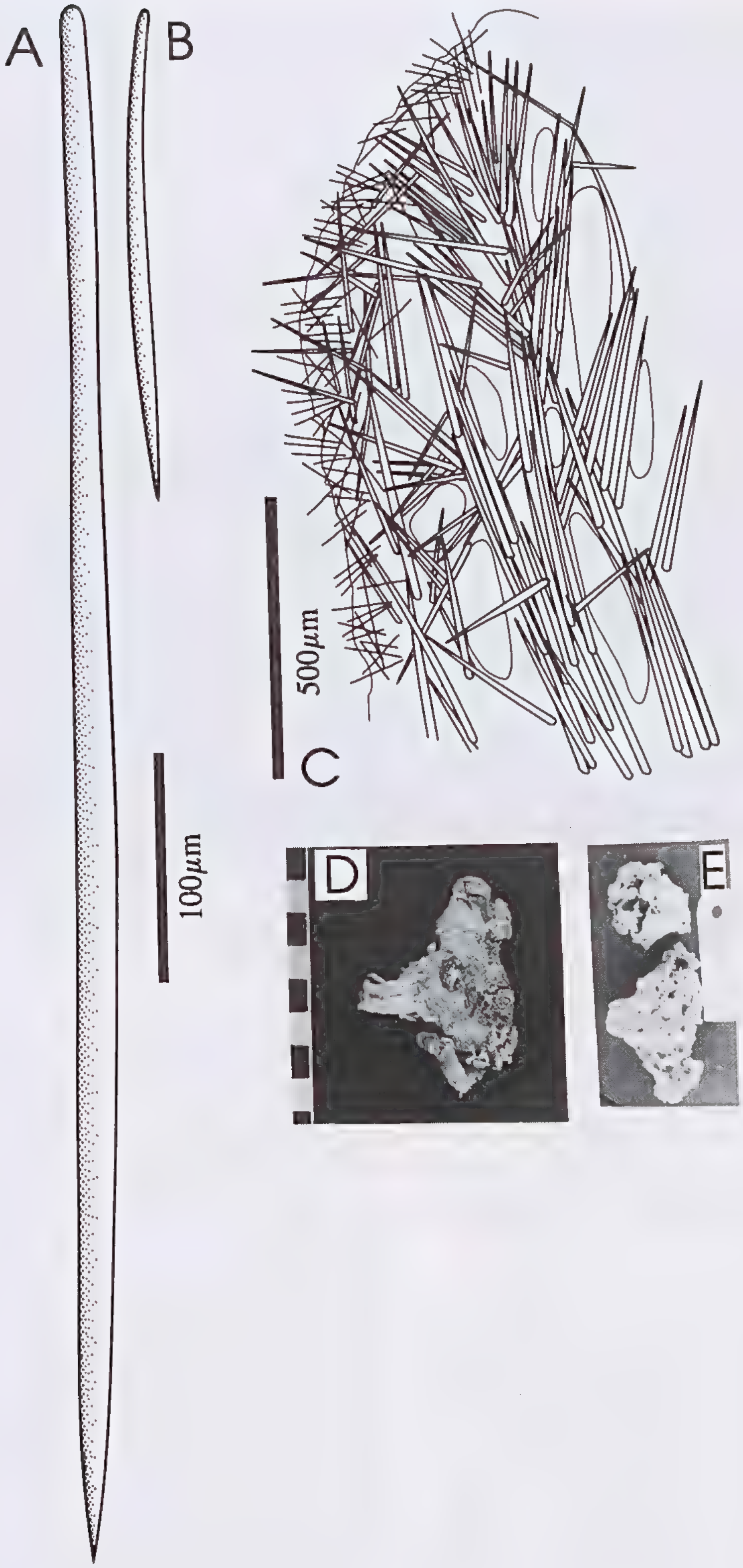

Fig. 17. *Amorphinopsis foetida* (Dendy). **A,** larger choanosomal style; **B,** smaller ectosomal style; **C,** peripheral skeletal structure (surface at left and top); **D,** preserved specimen QM G303677; **E,** live specimen (on deck).

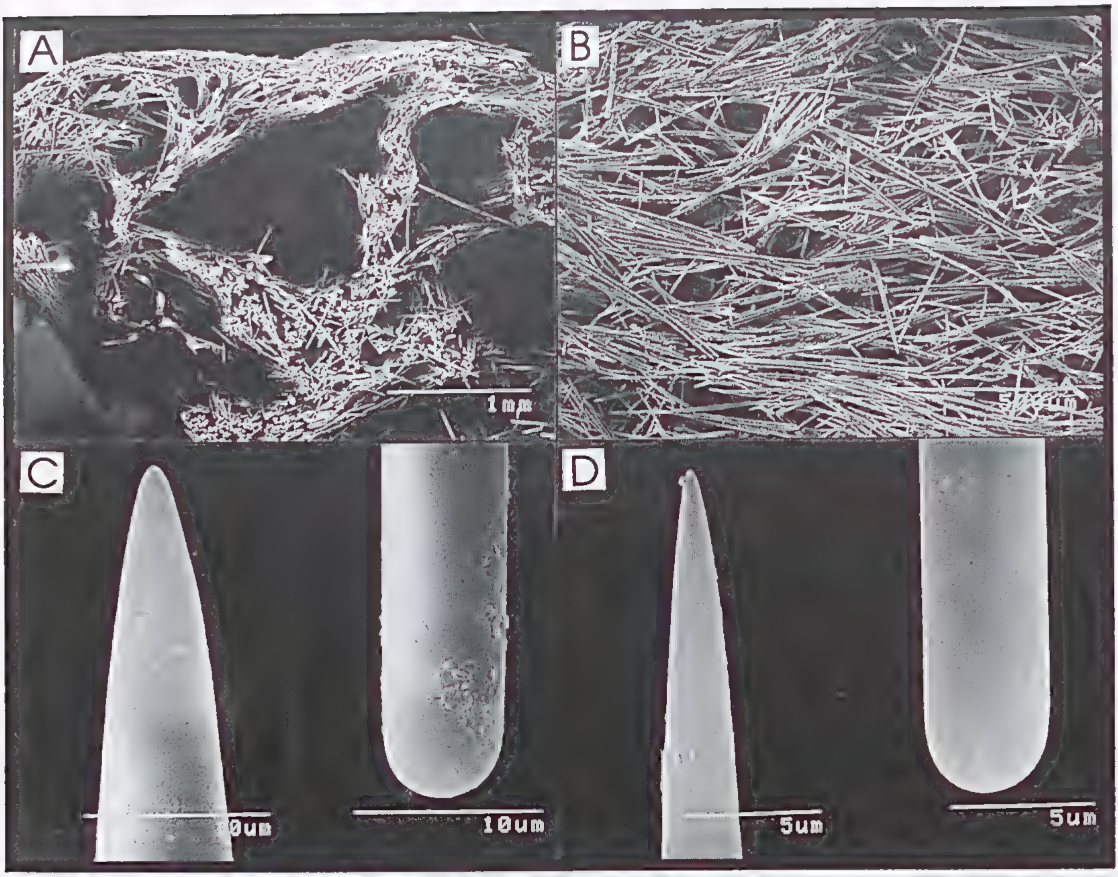

Fig. 18. *Amorphinopsis foetida* (Dendy). Specimen QM G303677. **A,** perpendicular section through skeleton in fistule region, showing cavernous reticulate construction; **B,** transverse section of ectosomal skeleton showing outer surface of sponge with a tangential layer of larger styles echinated by small styles; **C,** terminations on choanosomal styles; **D,** terminations on ectosomal styles.

Spicules. Choanosomal styles long, slender, straight or slightly curved at centre, nearly hastate (abruptly pointed), occasionally slightly telescoped points, with evenly rounded bases (length 448-(609.8)-794 µm, width 8-(16.4)-23 µm). Smaller ectosomal styles slender, straight, fusiform, with sharp points and evenly rounded bases (length 67-(106.8)-252 µm, width 3-(5.4)-8 µm).

Remarks. The possession of fistules and styloid spicules in this species suggests it could be placed in *Ciocalypta*. However, the fistules in *A. foetida* (short, squat, volcano-like) are unlike those characteristic of *Ciocalypta* (long, slender, pointed). Moreover, this species has an ectosomal skeleton with 'echinating' smaller styles over tangential tracts of larger choanosomal styles (whereas in *Ciocalypta* the smaller spicules are in bundles and also placed tangentially). Nevertheless, the possession of a core of spicules predominantly supporting the central portion of fistules, producing a wide-meshed cavernous reticulation supports the close relationship between the two genera.

This species is now relatively well known in the literature from several populations in the Indo-west Pacific (Sri Lanka, South China Sea, Moluccas and Arafura Sea), probably being a dominant sponge of the soft, shallow-water benthos. The specimen described above, the first record for Australia, agrees closely with Dendy's (1889) original description, including the characteristic low, volcano-like fistules on the upper surface, skeletal structure and spicule sizes, whereas spicule dimensions cited in the Indonesian records are larger than those reported in other populations. Dendy (1889) also records that the species has a strong fetid smell (hence the specific name) but this characteristic has not been subsequently recorded.

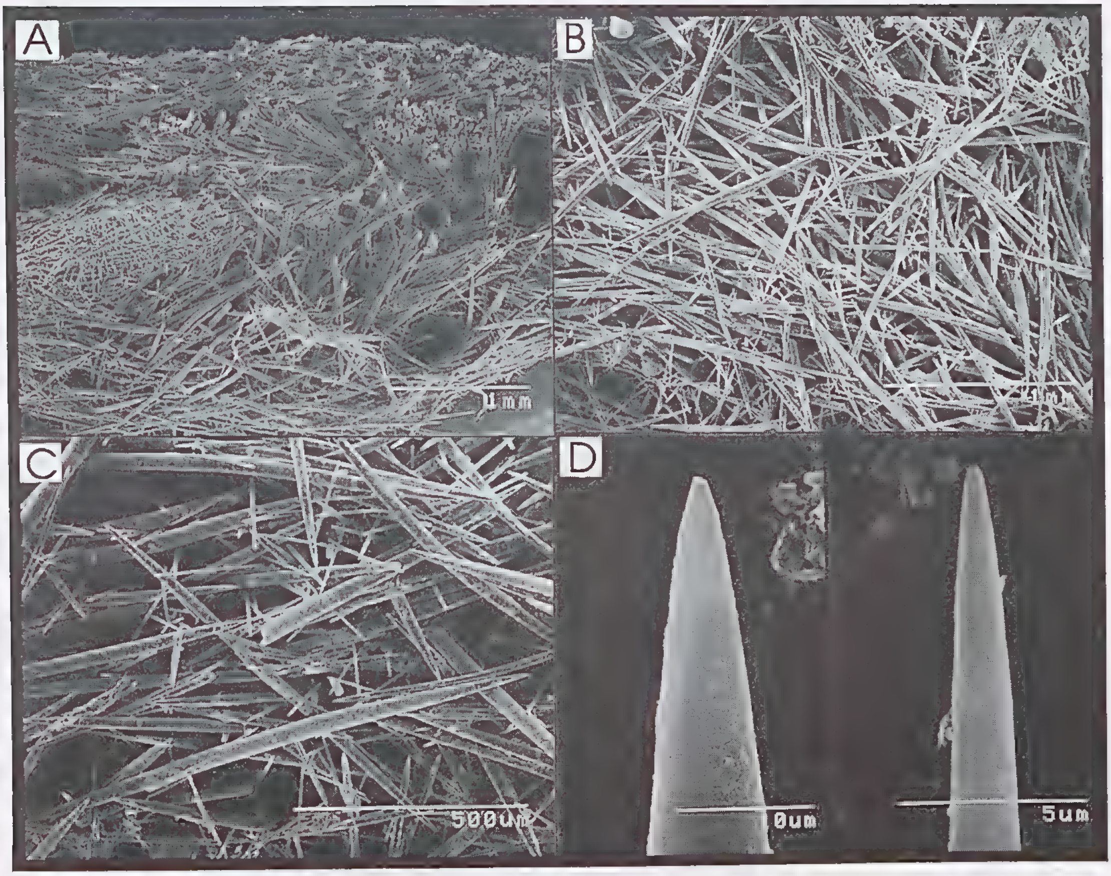

Fig. 19. *Amorphinopsis sacciformis* (Thiele). Specimen NTM Z2215. **A,** perpendicular section through skeleton, showing halichondroid reticulate choanosomal skeleton, oblique tracts in peripheral skeleton and tangential ectosomal layer (bottom of photo); **B,** transverse section of ectosomal skeleton showing outer surface of sponge with a tangential layer of larger oxeas echinated by small styles; **C,** closer view of tangential ectosomal skeleton; **D,** sharply pointed terminations on choanosomal oxeas (left) and ectosomal styles (right).

Amorphinopsis sacciformis (Thiele)

(Figs 19-20)

Ciocalypta sacciformis Thiele, 1900: 76, pl. 3, fig. 28 - Hentschel 1912: 125-126; - Kelly-Borges and Bergquist 1988: 132, pl. 2a.

Ciocalapata sacciformis - de Laubenfels, 1936: 134; - de Laubenfels 1954: 183-184, fig. 122.

Material. NTM Z2215: Vestey's Beach, Bullocky Point, Darwin, NT, 12°26.2'S, 130°49.9'E, intertidal, 21 January 1985, coll. J.N.A. Hooper, by hand.

Distribution. Moluccas, Arafura Sea; Palau Is., central west Pacific; Motupore Island, Papua New Guinea; and Darwin Harbour, 0-23 m depth.

Habitat. Intertidal rock and dead coral reef, frequently mud covered.

Description. Thinly encrusting under laterite rock boulders and covering bivalve shell, up to 8 mm thick following contours of substrate. Oscules not visible.

Colour. Yellow-brown in life (Munsell 7.5 YR 6/8), brown in ethanol.

Texture. Firm, compressible, harsh.

Surface. Hispid, not opaque.

Ectosomal skeleton. Indistinct, very thin surface peel with larger choanosomal oxeas lying tangential to surface and pointed ends of smaller ectosomal styles arranged paratangentially ('echinating') over larger spicules.

Choanosomal skeleton. Confused halichondroid reticulation of larger choanosomal oxeas, packed densely and bound together by small amount of collagen, in uni- and paucispicular bundles. Skeletal meshes oval, usually compressed, and only few larger spaces (lacunae)

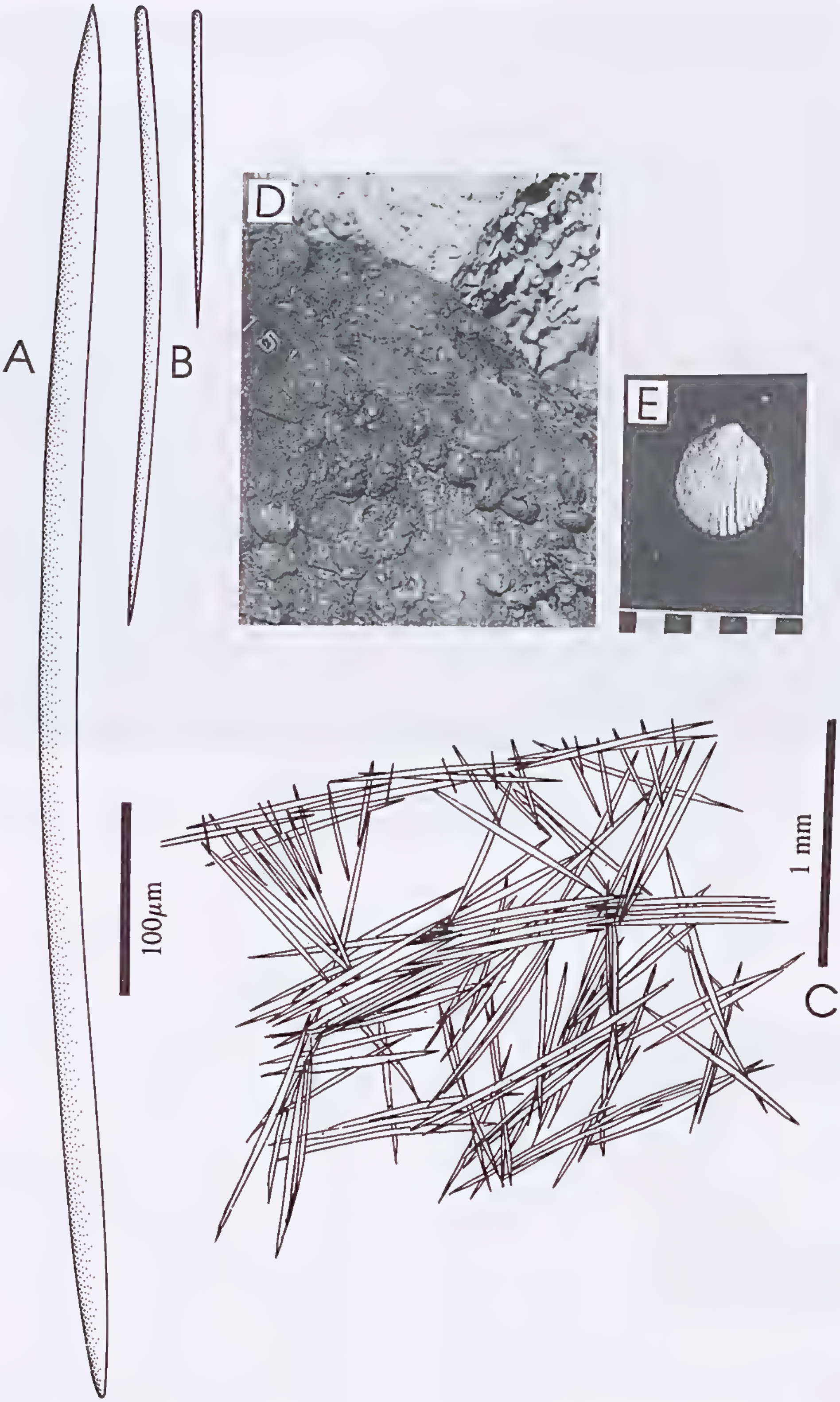

Fig. 20. *Amorphinopsis sacciformis* (Thiele). **A,** larger choanosomal oxea; **B,** smaller ectosomal styles; **C,** peripheral skeletal structure; **D,** live intertidal specimen (encrusting under coral boulder and bivalves); **E,** preserved specimen NTM Z2215 on bivalve.

visible in choanosomal or subectosomal regions. Subectosomal skeleton with more obliquely directed tracts supporting tangential ectosomal skeleton.

Spicules. Larger choanosomal oxeas straight or slightly curved at centre, with long tapering fusiform sharply pointed ends, in two size classes (length I 225-(318.5)-420 µm, width 5-(7.9)-10 µm; length II 540-(781.1)-1105 µm, width 11-(20.3)-35 µm)). Styles short, slender, fusiform, sharply pointed, with rounded or occasionally slightly subtylote bases (length 118-(213.4)-264 µm, width 3-(5.3)-9 µm).

Remarks. This species is atypical of *Amorphinopsis* in having a more compressed choanosomal skeleton than most other species, and only few small meshes between multispicular tracts, but this is considered here to be a function of its thinly encrusting (juvenile) growth form. The possession of smaller 'echinating' styles in the ectosomal skeleton indicates its affinities with *Amorphinopsis* rather than with *Ciocalypta* as suggested by previous authors. *Amorphinopsis sacciformis* is readily differentiated from other species of the genus in having two size categories of choanosomal oxeas, and both spicule dimensions and skeletal structures agree with those originally described for the species, although architecture is more noticeably wide-meshed in the Indonesian material (Thiele 1900; Hentschel 1912).

Genus *Halichondria* Fleming

Halichondria Fleming, 1828: 520.
Raspaigella Schmidt, 1868: 25.
Eumastia Schmidt, 1870: 42.
Spuma Miklucho-Maclay, 1870: 13.
Menanetia Topsent, 1896: 115.
Pyloderma Kirkpatrick, 1908: 51.
Halichondriella Burton, 1931: 137.
Trachyopsilla Burton, 1931: 138.
Ciocalapata de Laubenfels, 1936: 134.
Cioxeamastia de Laubenfels, 1942: 265.

Type species. *Spongia panicea* Pallas, 1766, by original designation.

Diagnosis. Massive amorphous growth forms. Choanosomal skeleton composed of poorly defined directionless spicule tracts; often two components recognisable: vaguely reticulate multispicular tracts and halichondroid criss-crossed single spicules dispersed between the major tracts, but major tracts may be sustantially reduced in favour of unispicular halichondroid skeleton (or vice versa). Cavities (lacunae) often occuring in choanosomal and subectosomal regions, with ascending choanosomal spicule tracts supporting ectosomal crust. Ectosomal skeleton invariably tangential to surface, usually easily peeled, composed of thin detachable crust of single spicules or multispicular tracts forming halichondroid criss-cross reticulation. Megascleres include predominantly oxeas of wide size ranges, commonly sharply pointed, but sometimes strongylote, stylote or rarely true styloid.

Remarks. There is a wide range of variation in the development of choanosomal spicule tracts amongst species of *Halichondria*, most having the major tracts obliquely directed or parallel to the surface. Similarly, development of the ectosomal skeleton varies from discrete tangential bundles to largely collagenous with fewer scattered tangential spicules (Van Soest *et al.* 1990). *Halichondria*, like *Hymeniacidon*, is characterised by the possession of a thin detachable ectosomal membrane bearing a unispicular, tangential, halichondroid criss-cross of oxeas, or sometimes vague bundles of spicule tracts lying tangential to the surface. The two genera are differentiated by their spicule geometry, having predominantly oxeas or exclusively styles, respectively.

Many species of *Halichondria* have been described from all oceans, although the genus has diversified to a larger extent in colder seas, including polar regions, and found predominantly in shallower waters (Diaz *et al.* 1991). Within the Indo-Australian region, 15 species have been described so far: *H. aciculata* (Carter), *H. arenacea* Dendy, *H. claviformis* Carter, *H. nigrocutis* (Carter) and *H. schmidti* (Dendy) from Bass Strait, Vic. (Carter 1885, 1886; Dendy 1895; Ayling *et al.* 1982); *H. latrunculioides* Ridley and Dendy and *H. prostata* Thiele from the Australian Antarctic Territory (Ridley and Dendy 1887; Thiele 1905; Hentschel 1914; Koltun 1964, 1976); *H. lycopodium* (Esper) and *H. cartilaginea* (Esper) from unspecified localities in northern Australia and Southern Indonesia (Topsent 1933); *H. mollissima* (Lendenfeld) from central NSW (Lendenfeld 1888); *H. phakellioides* Dendy and Frederick from the Houtman Abrolhos and Perth regions, WA (Dendy and Frederick 1924); *H. tyleri* (Bowerbank) widely distributed in northern Australia and Indonesia (Marshall 1892; Hentschel 1912; Burton 1934); *H. mertoni* (Hentschel) and *H.*

stalagmites (Hentschel) from the Aru Islands, Indonesia (Hentschel 1912); and *H. melichlora* (Sollas) from Straits of Malacca and Arafura Sea (Sollas 1902; Hentschel 1912) .

Halichondria tyleri (Bowerbank)
(Figs 21-22)

Ciocalypta tyleri Bowerbank, 1873: 21, pl. 4, figs 9-12.

Ciocalypta penicillus - Burton 1934: 564; Burton 1959: 264 (not *Ciocalypta penicillus* Bowerbank, 1864: 180).

Ciocalypta penicillus var. *gracilis* Topsent, 1897: 445, pl. 18, figs 6-7.

Ciocalypta tyleri var. *manaarensis* Dendy, 1889: 91.

Apatospongia fallax Marshall, 1892: 16, pl. 8, figs 1-5.

Type material. SYNTYPE - BMNH 1930.7.3.32: Port Elizabeth, South Africa, coll. Capt. Charles Taylor.

Other Material. - NTM Z592: Table Head, Port Essington, Cobourg Peninsula, NT, 11°13.5'S, 132°10.5'E, 3 m depth, 04 May 1982, coll. J.N.A. Hooper, SCUBA. NTM Z3286: SW side of cliff face, Table Head, Port Essington, 11°13.5'S, 132°10.5'E, 5 m depth, 11 September 1986, coll. J.N.A. Hooper and C. Johnson, SCUBA. NTM Z1358: Coral Bay, Port Essington, 11°11.3'S, 132°03.75'E, 6 m depth, 16 May 1983, coll. J.N.A. Hooper, SCUBA. NTM Z1395: same locality, 11°10.4'S, 132°02.8'E, 2m depth, 19 May 1983, coll. J.N.A. Hooper, SCUBA. NTM Z941: East Point 'bommies', Darwin, NT 12°24.05'S, 130°48.0'E, 12 m depth, 13 September 1982, coll. J.N.A. Hooper, SCUBA. NTMZ3133: Parry Shoals, 11°11.41'S, 129°43.01'E, 18m depth, 13 August 1987, coll. A.M. Mussig and NCI AIMS, SCUBA. NTM Z3410: 500 m east of Hermite Island, Monte Bello Islands, WA, 20°27.6'S, 115°32.8'E, 8m depth, 29 August 1988, coll. D. Low Choy and NCI AIMS, SCUBA.

Distribution. South Africa, Red Sea, Gulf of Manaar, Indo-Malayan region, northern Australia; Turtle Islands, North Direction Island, Great Barrier Reef, Qld.; East Point, Darwin Harbour; Parry Shoals, Arafura Sea; Port Essington, Cobourg Peninsula, NT; Monte Bello Islands, WA.

Habitat. Base of coral reefs, sandy substrate; intertidal to 81 m depth.

Description. Flattened or massive burrowing base extending below substrate for up to 30 mm, with long, thick, tapering fistules protruding above substrate, up to 125 mm long, 15 mm thick at base. Oscules surmounted on apex of most fistules, although some fistules blind and merely sharply pointed.

Colour. Live colouration mottled mauve-brown (Munsell 2.5R 5/6) and mauve-green (5Y 5/4) fistules and beige base (5Y 8/4); mauve-beige in ethanol.

Texture. Compressible, flexible, relatively easily torn.

Surface. Opaque and membranous with drainage channels running down sides of fistules, visible through ectosome. External surface even, slightly conulose and minutely hispid.

Ectosomal skeleton. Thick, continuous, dense spiculous layer, easily peeled from sponge surface, with multispicular tangential skeletal tracts composed mainly of larger oxeas, overlayed by unispicular paratangential tracts or plumose tufts of smaller oxeas. Ectosomal skeleton associated with moderate quantities of pigmented collagen.

Choanosomal skeleton. Interior of choanosome a confusion of single spicules, mostly large, becoming more organised into radial bundles of spicules towards surface. In some specimens, medium-sized spicules forming distinct tracts approximately 20-50 spicules in width, traversing subdermal lacunae perpendicular to surface. In fistules choanosomal skeleton compressed, confined to central portion of skeleton, with huge subectosomal spaces (up to 5 mm diameter) and only few large subectosomal multispicular tracts support ectosomal peel. Collagen present in interior of choanosome and closely associated with spicule tracts.

Spicules. Two size classes of oxeas: larger choanosomal oxeas slightly or moderately curved at centre, tapering fusiform, sharply pointed, occasionally asymmetrical anisoxeote (length 423-(536.7)-665 μm, width 8-(14.4)-22 μm); smaller ectosomal oxeas straight or slightly curved at centre, sharply pointed fusiform (length 150-(205.4)-312 μm, width 3-(4.2)-5 μm).

Remarks. Under the traditional definitions of halichondrids, this species would have been included in *Ciocalypta*, having a fistulose growth form, plumose ectosomal skeleton of smaller spicules overlaying a tangential skeleton of larger choanosomal megascleres, and with supporting spicules located mainly at the core of fistules (as

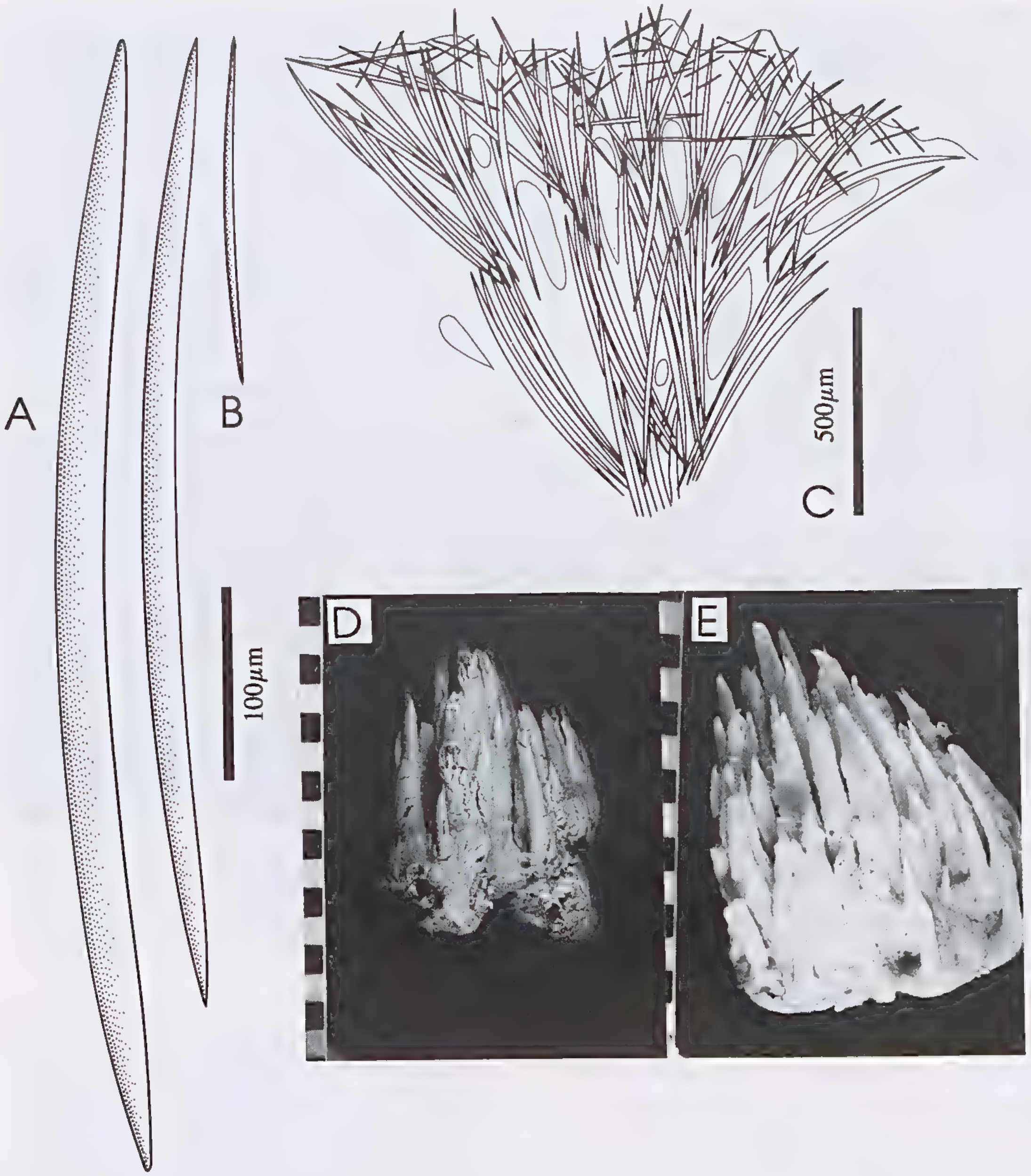

Fig. 21. *Halichondria tyleri* (Bowerbank). **A,** larger choanosomal oxeas; **B,** smaller ectosomal oxea; **C,** peripheral skeletal structure; **D,** preserved specimen NTM Z592; **E,** preserved specimen NTM Z1358.

opposed to peripheral supporting spicules found in *Petromica*). However, given that all spicules are oxeas (not styles), this species is referred to *Halichondria* under the revised criteria of Van Soest *et al.* (1990) and Diaz *et al.* (1991) which hypothesises that fistules are an ecological adaptation for colonising soft substrata, and consequently they have been independently developed throughout various genera of Halichondriidae, and are also found in some species of *Topsentia*, *Ciocalypta*, and *Petromica*, as well as many other sponge orders.

Burton (1959) synonymised many quite different species, including *Ciocalypta tyleri*, under the name *C. penicillus*. Most of this synonymy is now rejected following examination of relevant type material. Of relevance to the Australian fauna, Hooper and Wiedenmayer (1994) listed several species in synonymy with *H. tyleri*, following Burton (1959), but these can now be

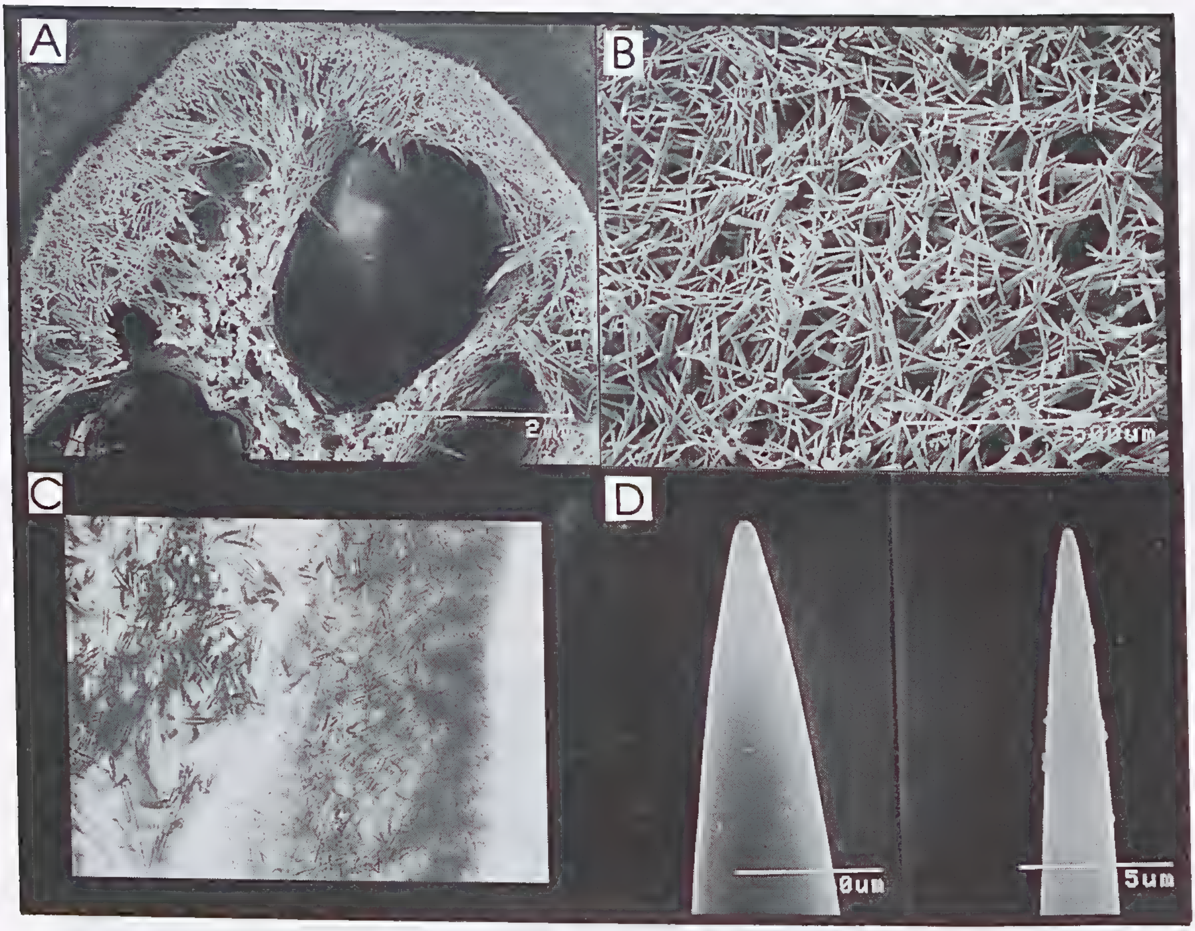

Fig. 22. *Halichondria tyleri* (Bowerbank). Specimen NTM Z941. **A,** perpendicular section through skeleton of fistule, showing choanosomal skeleton restricted to central portion of fistules, extremely cavernous subectosomal skeleton and thick paratangential ectosomal skeleton; **B,** transverse section of ectosomal skeleton showing outer surface of sponge with a multispicular and unispicular tangential skeletons; **C,** light micrograph of section through choanosomal skeleton showing compressed halichondroid reticulation in central portion of skeleton and halichondroid plumose subectosomal region; **D,** sharply pointed spicule terminations on larger oxeas (left) and smaller oxeas (right).

allocated more accurately now that we have had access to type material. Of Burton's (1959) synonymised species, *Ciocalypta heterostyla* Hentschel (1912) and *C. rutila gracilis* Hentschel (1912) (which belong to *Ciocalypta*), and *C. mertoni* Hentschel (1912) (which belongs to *Halichondria*), are not fistulose, they do not have exclusively oxeote spicules, and are not closely related to *H. tyleri*. *Ciocalypta penicillus aciculata* Carter (1885) is fistulose, with tapering "sub-pinlike" spicules (which are subacerate styles, with the thickest part of the spicule near the point rather than the base), and lacks the specialised tangential ectosomal skeleton characteristic of *Ciocalypta*. It is probably most appropriately referred to *Halichondria*, although this needs to be established from recollection of fresh material. *Stylotella polymastia* Lendenfeld (1888) is also a *Ciocalypta* (Hallmann, 1914), and not closely related to *H. tyleri*. *Sigmaxinella papillata* Brondsted (1923), *Axinella colvilli* Brondsted (1924) and *Hymeniacidon novaezelandiae* Brondsted (1924) have both large choanosomal styles and small ectosomal oxeas and a fistulose growth form. Bergquist (1970) subsequently included these three species from New Zealand into synonymy with the European species *Ciocalypta penicillus* Bowerbank, but this conspecificity is very unlikely. They probably represent a single, distinct New Zealand species, possibly best allocated to *Amorphinopsis* or *Ciocalypta* (depending on whether ectosomal spicules are merely tangential or echinating). The name *C. papillata* (Brondsted) is the oldest available name for this taxon. As a consequence of rejecting Burton's (1959) synonymy, *Halichondria tyleri* is restricted now to Indo-west Pacific populations, extending into the Pacific

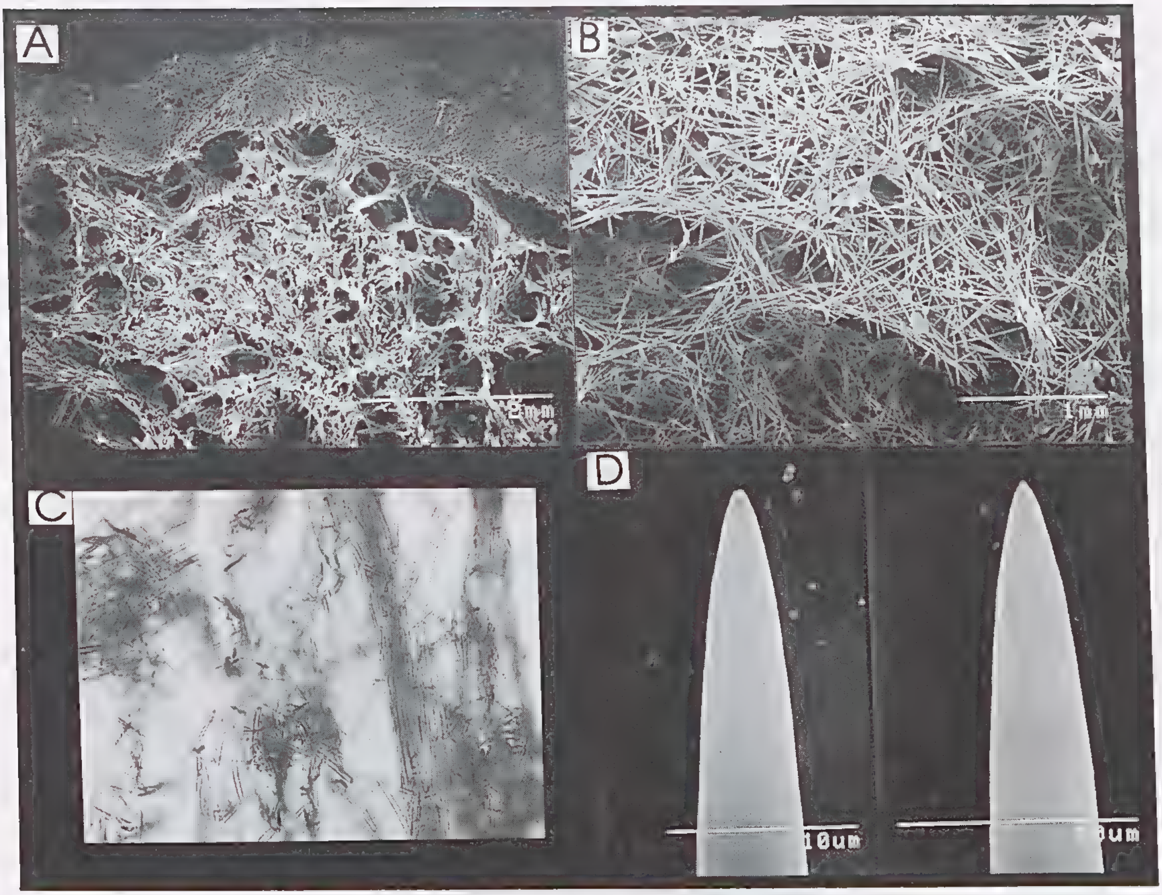

Fig. 23. *Halichondria vansoesti* sp. nov. Holotype NTM Z2678. **A,** perpendicular section through skeleton showing distinctive cavernous, reticulate subectosomal skeleton and thin tangential ectosomal peel; **B,** transverse section of ectosomal skeleton showing outer surface of sponge with a mostly uni- or paucispicular tangential layer; **C,** light micrograph of section through deeper choanosomal skeleton showing halichondroid reticulation of multispicular tracts; **D,** faintly telescoped points of larger oxeas (left) and smaller oxeas (right).

only as far as the northern Great Barrier Reef. Several other species with similar growth forms but differing in various aspects of their spiculation and skeletal structures have been recently collected from central, southern Queensland and New South Wales waters, and these represent distinct sibling species, some at least still undescribed. These will be dealt with in a second part to this present contribution (Hooper *et al.*, in prep.).

Halichondria tyleri is distinctive in its burrowing fistulose growth form, with sharply pointed fistules with small terminal oscules, mauve-brown live colouration, slightly conulose surface with clearly visible subectosomal drainage canals, cavernous skeletal construction in the peripheral skeleton (not in the central portion of the skeleton), exclusively oxeote spicules both of moderate size range (mean 540 x 14 µm and 205 x 4 µm), and sharply pointed spicule terminations (no telescoped endings). These specific attributes distinguish it from other fistulose species including those mentioned above and *H. vansoesti* sp. nov.

Halichondria vansoesti sp. nov.
(Figs 23-24)

Type material. HOLOTYPE - NTM Z2648: East Point, Darwin, NT, 12°24.5'S, 130°48.0'E, 12m depth, 3 April 1986, coll. J.N.A. Hooper and A.M. Mussig, SCUBA. PARATYPE - QM G303450: W. side Fish Reef, Bynoe Harbour, NT, 12°26.1'S, 130°26.5'E, 11 m depth, 26 September 1993, coll. J.N.A. Hooper and L.J. Hobbs, SCUBA.

Material. NTM Z84: Coral Bay, Port Essington, Cobourg Peninsula, NT, 11°11.5'S, 132°02.0'E, 4 m depth, 18 October 1981, coll. J.N.A. Hooper and P.N. Alderslade, SCUBA. NTM Z2678: East Point, Darwin, NT, 12°24.50'S, 130°48.0'E, 12 m depth, 3 April

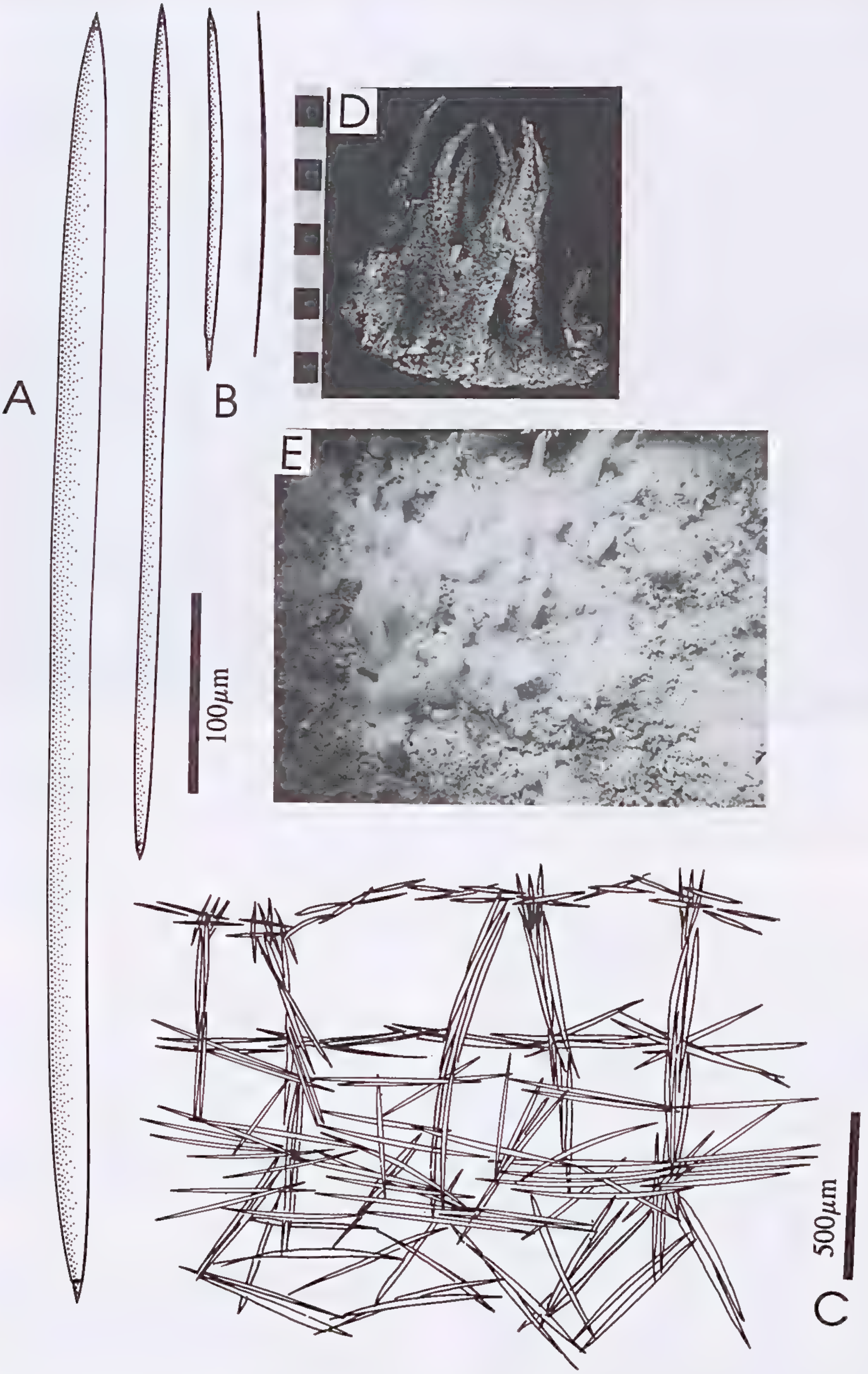

Fig. 24. *Halichondria vansoesti* sp. nov. **A,** larger choanosomal oxeas; **B,** smaller ectosomal oxeas; **C,** peripheral skeletal structure; **D,** preserved specimen NTM Z84; **E,** live subtidal paratype QM G303450.

1986, coll. J.N.A. Hooper and A.M. Mussig, SCUBA. QM G300815: E of Gove Peninsula, Gulf of Carpentaria, Qld, 12°37.1'S, 136°49.3'E, 26 m depth, 23 November 1991, coll. S.J. Cook, RV *Southern Surveyor*, dredge.

Distribution. East Point, Darwin Harbour; Fish Reef, Bynoe Harbour; Cobourg Peninsula, NT; eastern Gulf of Carpentaria.

Habitat. Rocky reef, reef slope, sandy substrate; subtidal 4-26 m depth.

Description. Flattened base burrowing only shallow distance into substrate; top of base with long, tapering, pointed fistules protruding up to 250 mm above substrate; base approximately 25 mm thick, fistules up to 200 mm long, 25 mm diameter at base. Oscules large, up to 3 mm diameter in preserved state, located on basal plate in between fistules.

Colour. Completely unpigmented, white in life and in ethanol.

Texture. Firm, compressible, fistules flexible but easily torn and detachable from basal plate.

Surface. Transparent, parchment-like membrane with subectosomal cavities clearly visible beneath. Surface of fistules regularly conulose, minutely hispid, with longitudinal striations visible subectosomally (presumably peripheral skeletal tracts running longitudinally from base to tip of fistule).

Ectosomal skeleton. Detachable relatively thick peel formed by halichondroid reticulation of mostly smaller ectosomal oxeas, in uni- or paucispicular tracts, lying tangential to surface. Ectosomal skeleton varying greatly in thickness, thicker in region of base than at apex of fistules. In addition to tangential skeleton, sparse plumose tufts of smaller spicules occurring at junction where choanosomal tracts meet ectosome, standing paratangential to and just protruding through surface, producing prominent surface conules.

Choanosomal skeleton. Confused halichondroid skeleton of mostly directionless multispicular tracts, 20-50 spicules in width, with some single spicules also dispersed between tracts. Spicule tracts composed of both large and small oxeas, becoming more perpendicular closer to surface and forming distinctive cavernous subectosomal region. Moderate quantities of collagen present in mesohyl associated with spicule tracts.

Spicules. Oxeas in two size classes. Larger choanosomal oxeas straight or slightly curved at centre, fusiform, with slightly telescoped points (length 470-(558.3)-615 μm, width 8-(11.5)-15 μm). Smaller ectosomal oxeas straight or very slightly curved at centre, fusiform, with slightly telescoped points (length 200-(265.7)-425 μm, width 2-(3.8)-6 μm).

Etymology. For Dr Rob Van Soest, Zoological Museum, University of Amsterdam, for extensive contributions to the systematics of sponges, particularly the contemporary classification of Halichondriidae.

Remarks. *Halichondria vansoesti* and *H. tyleri* are sibling species sharing a burrowing, fistulose growth form and comparable spicule sizes (mean lengths and widths 560 x 11 μm and 265 x 4 μm, versus 540 x 14 μm and 205 x 4 μm, for choanosomal and ectosomal oxeas, respectively). They are clearly not conspecific, differing substantially in their field characteristics (the fistules of *H. vansoesti* being consistently white alive, whereas those of *H. tyleri* are mauve-brown), ectosomal skeletal structure (marginally thicker in *H. vansoesti*), choanosomal skeletal structure (whereby in *H. vansoesti* the most cavernous part of the fistulose skeleton is found near the periphery, and in this region spicule tracts become reticulate, whereas in *H. tyleri* the deeper, central choanosomal region is prominently cavernous whereas the peripheral, subectosomal skeleton is dense and radial in construction), and spicule geometry (with telescoped points on spicules as opposed to sharply pointed spicules).

Halichondria phakellioides Dendy and Frederick

(Figs 25-26)

Halichondria phakellioides Dendy and Frederick, 1924: 498-499, pl. 26, fig. 10. - Burton 1934: 600, pl. 2, fig. 1.

Type material. HOLOTYPE - BMNH 1925.11.1.185: Sandy Isle, Houtman-Abrolhos, WA, coll. W. Dakin.

Other Material. NTM Z900: East Point Aquatic Reserve, off Dudley Point, Darwin, NT, 12°25.0'S, 130°48.04'E, 10 m depth, 31 August 1982, coll. J.N.A. Hooper, SCUBA. NTM Z2063: same locality, 12°25.0'S, 130°48.4'E, 6-10 m depth, 10 May 1984, coll. J.N.A. Hooper and P.N. Alderslade, SCUBA. NTM Z2255: same locality, 12°24.5'S, 130°48.0'E, 10 m depth, 12 April 1985, coll. J.N.A. Hooper and C. Johnson, SCUBA. NTM Z2610, 2623, 2643, 2652, 2674: same locality, 12°24.5'S, 130°48.0'E, 9-12 m depth, 03 April 1986, coll. J.N.A. Hooper and A.M. Mussig, SCUBA. NTM Z935: same locality, 12°24.05'S, 130°48.0'E, 12 m depth, 13 September 1982, coll. J.N.A. Hooper, SCUBA. QM G303320: East Point 'bommies', East Point Aquatic Life Reserve, 12°24.5'S, 130°48.8'E, 10m depth, 23 September 1993, coll. J.N.A. Hooper and L.J. Hobbs, SCUBA. QM G303261: S of South Shell I., East Arm, 12°29.8'S, 130°53.5'E, intertidal, 19 September 1993, coll. J.N.A. Hooper and L.J. Hobbs, by hand. NTM Z241: Indian I., 12°35.0'S, 130°33.0'E, 3 m depth, 18 November 1981, coll. Byers, P., FV *Skelton*, snorkel. QM G303448: Fish Reef, W side near wreck of HMAS *Brisbane*, Bynoe Harbour, NT 12°26.1'S, 130°26.5'E, 11m depth, 2 September 1993, coll. J.N.A. Hooper and L.J. Hobbs. NTM Z3929: Bay N side of Cumberland Strait, Wessel Is, NT 11°27.5'S, 131°28.8'E, 20 m depth, 14 November 1990, coll. J.N.A. Hooper, SCUBA. NTM Z621: Unnamed shoal, N of Melville I., NT, 11°38.23'S, 129°51.0'E, 24 m depth, 17.v.1982, coll. R. Lockyer and B. Thom, SCUBA. NTM Z3077: Parry Shoals, 11°11.41'S, 129°43.01'E, 18 m depth, 13 August 1987, coll. A.M. Mussig and NCI AIMS, SCUBA. NTM Z3139: same locality, 11°12.28'S, 129°42.71'E, 16m depth, 14 August 1987, coll. A.M. Mussig and NCI AIMS, SCUBA. NTM Z3075: same locality, 11°11.72'S, 129°43.26'E, 16 m depth, 12 August 1987, coll. Mussig, AM and NCI AIMS, SCUBA. NTM Z3349: 8 km from shore, NW corner of Herald Reef, Coolga Point, WA, 21°29.5'S, 115°17.1'E, 5 m depth, 25 August 1988, coll. D. Low Choy and NCI AIMS, SCUBA. NTM Z3395: 50 m from shore, 3 km west of Hermite Island, Monte Bello Islands, 20°27.1'S, 115°34.2'E, 6 m depth, 29 August 1988, coll. D. Low Choy and NCI AIMS, SCUBA. NTM Z3361: 5 km from shore, Flinders Shoals, N of Mary Anne Island, Mary Anne Passage, WA, 25°14.2'S, 115°28.2'E, 8 m depth, 25 August 1988, coll. D. Low Choy and NCI AIMS, SCUBA.

Distribution. Swan River region and Houtman-Abrolhos, southern WA; Herald Reef, Mary Anne Island and Monte Bello Islands, northern WA; East Point, Dudley Point and East Arm, Darwin Harbour; Indian Island and Fish Reef; Bynoe Harbour; Wessel Islands, Gove Peninsula; Parry Shoals and Melville Island, Arafura Sea, NT; ? unspecified locality, Great Barrier Reef, Qld.

Habitat. Coral rubble and soft substrates, usually between patches of reef; intertidal to 30 m depth.

Description. Erect, buttressed flattened ridges. Base fixed to substrate by basal plate, attached to fragments of coral or shell, usually burrowing into soft substrate; ridges ('fistules') thick, flat (up to 220 mm long, 50 mm wide, 30 mm thick) growing in several planes, anastomosing and becoming buttressed or digitate in some specimens. Oscules small (330-500 µm diameter) but conspicuous and scattered on lateral surfaces of ridges, each with slightly raised membraneous lip.

Colour. Yellow-brown to pale orange alive (Munsell 2.5Y 8/10 - 5YR 7/10), beige to grey in ethanol.

Texture. Harsh, firm but compressible, can be torn.

Surface. Surface smooth, even between large digitate projections (ridges); usually membraneous and clearly detachable (although in some material surface roughened and minutely conulose due to poor preservation). Surface membrane translucent, with subectosomal lacunae and drainage channels clearly visible below.

Ectosomal skeleton. Ectosomal skeleton consisting of distinct tangential crust of both single spicules and bundles of mostly medium-sized spicules, forming prominent 'skin'. Paratangential tracts of subectosomal spicules meeting tangential surface layer at regular intervals, giving ectosome patchy or striated appearance in cross-section; ascending spicule tracts may protrude slightly through tangential layer. In transverse section, ectosome nearly regularly reticulate, with cross-hatched spicule tracts five to eight spicule widths (20-50 µm in diameter) forming oval meshes 80-15 µm in diameter, distinctly detachable and clearly offset from cavernous subectosomal skeleton. Small amounts of collagen present in ectosomal layer bonding tangential spicule tracts.

Choanosomal skeleton. Skeletal structure halichondroid reticulate in deeper choanosomal skeleton and cavernous reticulate in subectosomal peripheral skeleton. Deeper choanosomal region more disorganised than peripheral skeleton, largely composed of single spicules forming directionless halichondroid reticulation (criss-cross), comprising both large and small oxeas, whereas only large and medium-sized spicules comprise tracts or bundles of approximately 20-50 spicules in width (150-250 µm in diameter). Multispicular tracts forming prominent ascending lines arising to surface, with tracts aligned perpendicular to surface, supporting ectosomal skeleton, and traversing large subdermal cavities; cavities (lacunae) varying greatly in size between specimens ranging from 200-2000 µm diameter. Spongin fibres not evident but sparse collagen present in mesohyl closely associated with spicule tracts.

Spicules. Oxeas in three size classes, all fusiform, slightly curved at centre or straight; larger ones usually faintly telescoped, sometimes sharply pointed or rarely styloid; smaller ones include both prominently telescoped and sharply pointed forms (I: length 314-(444.6)-578 µm, width 10-(13.1)-20 µm; II: length 195-(230.6)-275 µm, width 4-(6.9)-12 µm; III: length 58-(196.8)-266 µm, width 1-(2.2)-3 µm).

Remarks. This species is probably widely distributed in tropical and subtropical waters of Australasia, although its recorded distribution so far is restricted to the southwest and northwest coasts, from the Perth region, WA, to the Wessel Islands, NT. The single Pacific record is based on a specimen collected by Saville Kent (Burton 1934), with no specific locality data given. This record remains unsubstantiated, although Burton (1934) states that the Queensland specimen agrees in all details to the holotype.

One of the prominent features of *H. phakellioides* is the clearly detachable tangential ectosomal skeleton, which peels off the sur-

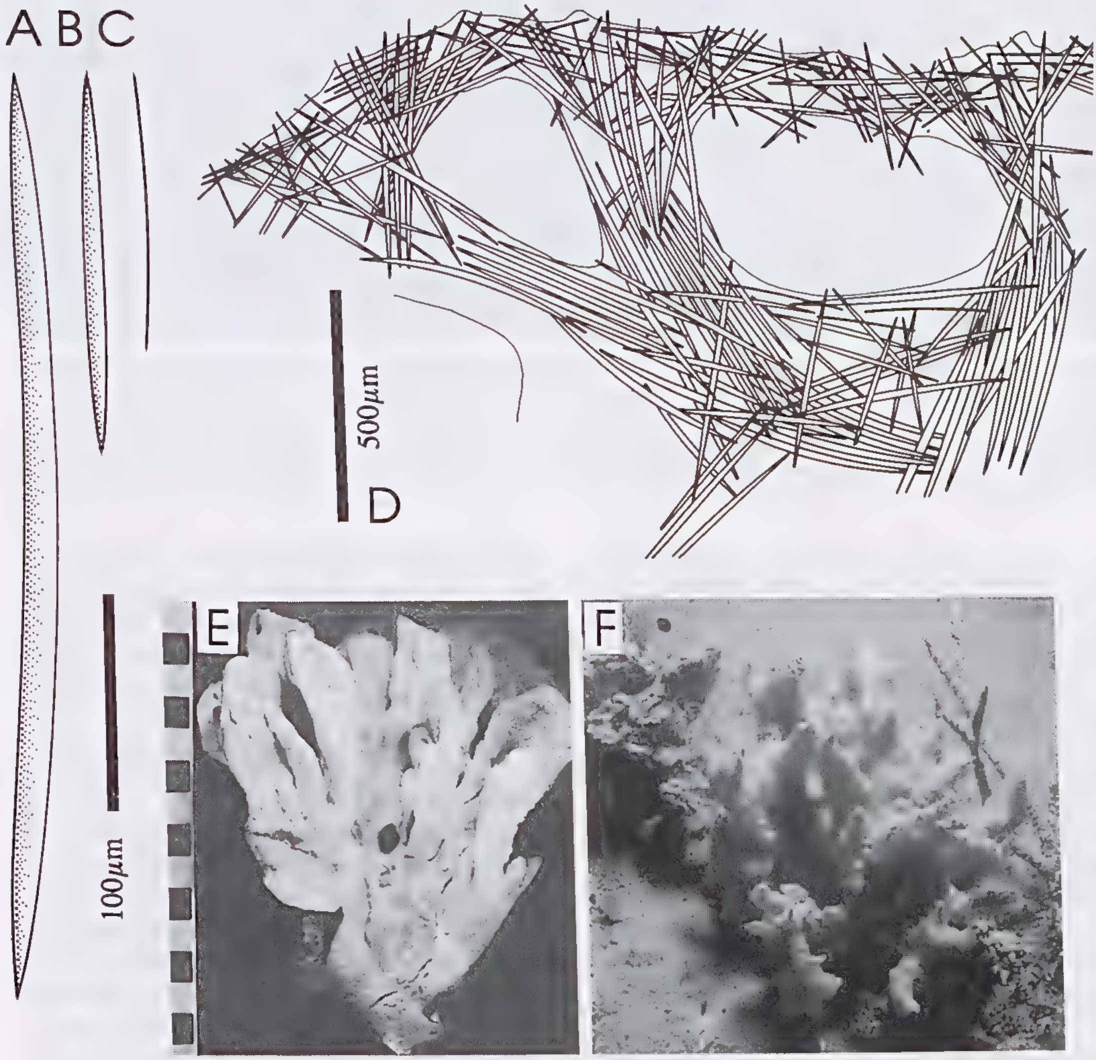

Fig. 25. *Halichondria phakellioides* Dendy and Frederick. **A,** larger oxeas; **B,** medium sized oxeas; **C,** smaller oxeas; **D,** peripheral skeletal structure; **E,** preserved specimen NTM Z900; **F,** live subtidal specimen NTM Z2610.

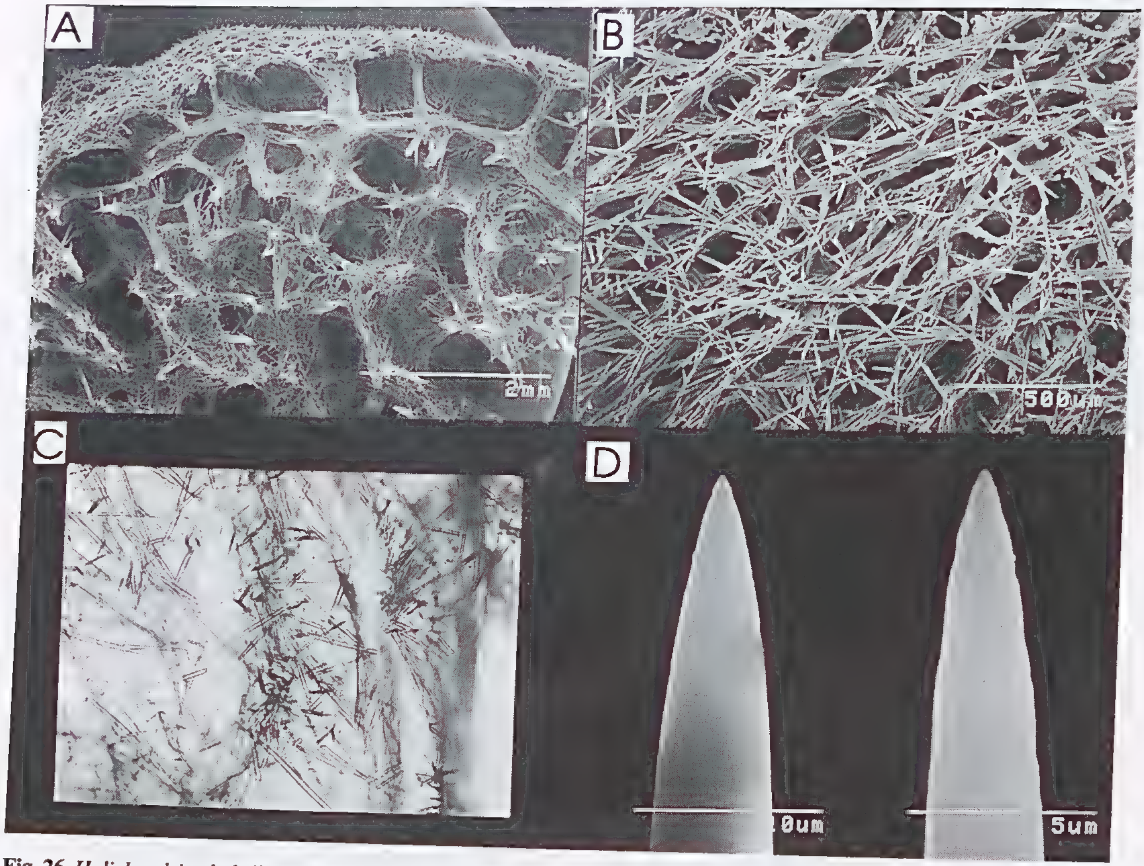

Fig. 26. *Halichondria phakellioides* Dendy and Frederick. Specimen NTM Z2255. **A,** perpendicular section through skeleton of erect ridge, showing distinctive cavernous and reticulate nature of subectosomal skeleton and spicule columns supporting thin tangential ectosomal skeleton; **B,** transverse section of ectosomal skeleton showing outer surface of sponge with a tangential layer of mostly multispicular tracts composed of both larger and smaller oxeas, forming cross-hatched reticulation; **C,** light micrograph of section through deeper choanosomal skeleton showing halichondroid reticulation of mostly single spicules; **D,** telescoped terminations on larger oxeas (left) and smaller oxeas (right).

face relatively easily, exposing a cavernous reticulate skeleton beneath (often infested with shrimps and polychaete worms). Initially this species was subdivided into two morphs, one with and the other without a detachable ectosomal skeleton, but it was eventually recognised that this feature was largely dependent on the state of preservation of material (in badly preserved material the surface was minutely conulose, lacking the tangential ectosomal peel). Another important feature of this species, making it easily recognisable in the field, is the erect buttressed growth form and yellowish live colouration (although in deeper or murkier waters pigments may be absent entirely), and harsh texture of the ectosomal skeleton. In its erect, buttressed growth form this species is very similar to *Leucophloeus massalis* Carter from southern Australia (in particular to an unpublished variety *alata* of Carter's (1883) in the BMNH, with 'hypotypes' BMNH 1886.12.15.454 and 473 from Fremantle, WA). *Leucophloeus massalis*, however, has much thicker lamellae than *H. phakellioides*, and exclusively stylote megascleres which places it in *Ciocalypta* (Hooper and Wiedenmayer 1994). Other species referred to Halichondriidae at one time or another with similar erect buttressed growth forms include: *L. compressus* Carter (1883) from Westernport Bay, Victoria. (syntype BMNH 1886.12.15.9) and *Axinella solida* Carter, (1885) from Bass Strait, Vic. (lectotype BMNH 1887.7.11.24); *L. compressus* belongs to *Pseudoclathria* (family Crellidae) (Dendy 1897), and *A. solida* belongs to *Rhaphoxya* (family Axinellidae) (Hooper and Lévi 1993b).

Three spicule sizes are differentiated in the description of *H. phakellioides*, although realistically only two sizes are clearly distinguished (the smallest category probably being juvenile

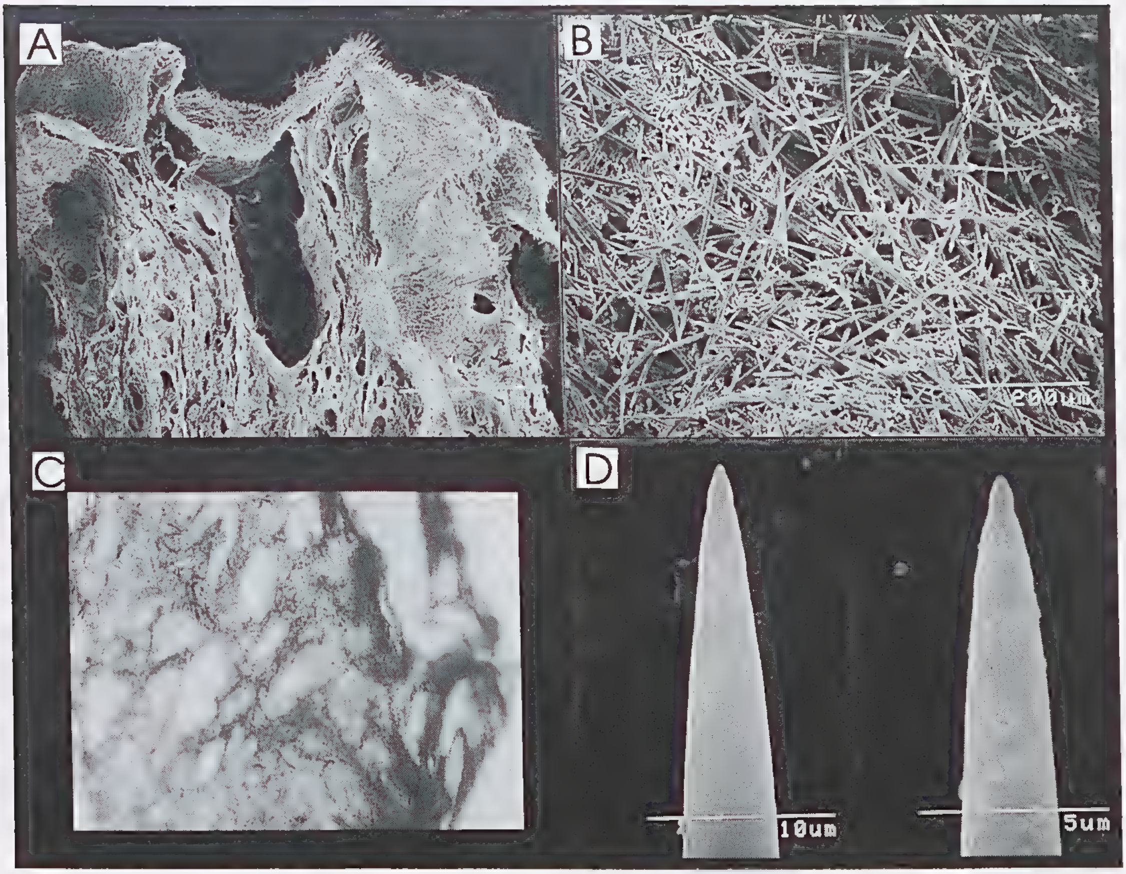

Fig. 27. *Halichondria stalagmites* (Hentschel). Specimen NTM Z131. **A,** perpendicular section through skeleton of fistule, showing multispicular halichondroid reticulate skeleton, large lacunae near in the subectosomal region, and thin tangential ectosomal peel on convoluted part of surface (top of photo); **B,** transverse section of ectosomal skeleton showing outer surface of sponge with a thin tangential layer of both larger and smaller oxeas without apparent difference in their distribution; **C,** light micrograph of section through peripheral skeleton showing extensive canal system in subectosomal region; **D,** slightly telescoped terminations on larger oxeas (left) and smaller oxeas (right).

representatives of the medium-sized oxeas). There is no clear size-class localisation of spicules (such as seen in *Amorphinopsis* and *Ciocalypta*), although smaller spicules are mostly found scattered between the multispicular tracts.

Halichondria stalagmites (Hentschel)
(Figs 27-28)

Ciocalypta stalagmites Hentschel, 1912: 126, pl. 21, fig. 60.

Type material. SYNTYPE - SMF 1595: Meriri and Leer Is., Aru Is, Arafura Sea, Indonesia, 31 March 1908, coll. H. Merton, 10 m depth, dredge.

Other Material. NTM Z131: Sandy Island No. 2, Cobourg Peninsula, NT, 11°05.5'S, 132°17.0'E, 10 m depth, 21 October 1981, coll. J.N.A. Hooper and P.N. Alderslade, SCUBA. NTM Z1097: East Point, Darwin, NT, 12°25.0'S, 130°48.4'E, 6-7 m depth, 22 December 1982, coll. J.N.A. Hooper, SCUBA. NTM Z2651: same locality, 12°24.5'S, 130°48.0'E, 9-12 m depth, 3 April 1986, coll. J.N.A. Hooper, A.M. Mussig, A. Howard and C. Hood, SCUBA. NTM Z1991: W side Weed Reef, Darwin, NT, 12°29.2'S, 130°47.1'E, 8 m depth, 11 May 1984, coll. J.N.A. Hooper, P.J. Horner and P.N. Alderslade, SCUBA. NTM Z3147: Parry Shoals, Arafura Sea, NT, 11°12.53'S, 129°42.08'E, 16 m depth, 15 August 1987, coll. A.M. Mussig and NCI, SCUBA.

Distribution. Arafura Sea, Indonesia; Darwin Harbour, Cobourg Peninsula and Parry Shoals, Arafura and Timor Seas, NT.

Habitat. Sand, mud, coral rubble, usually with base burrowing slightly into substrate; 6-16 m depth.

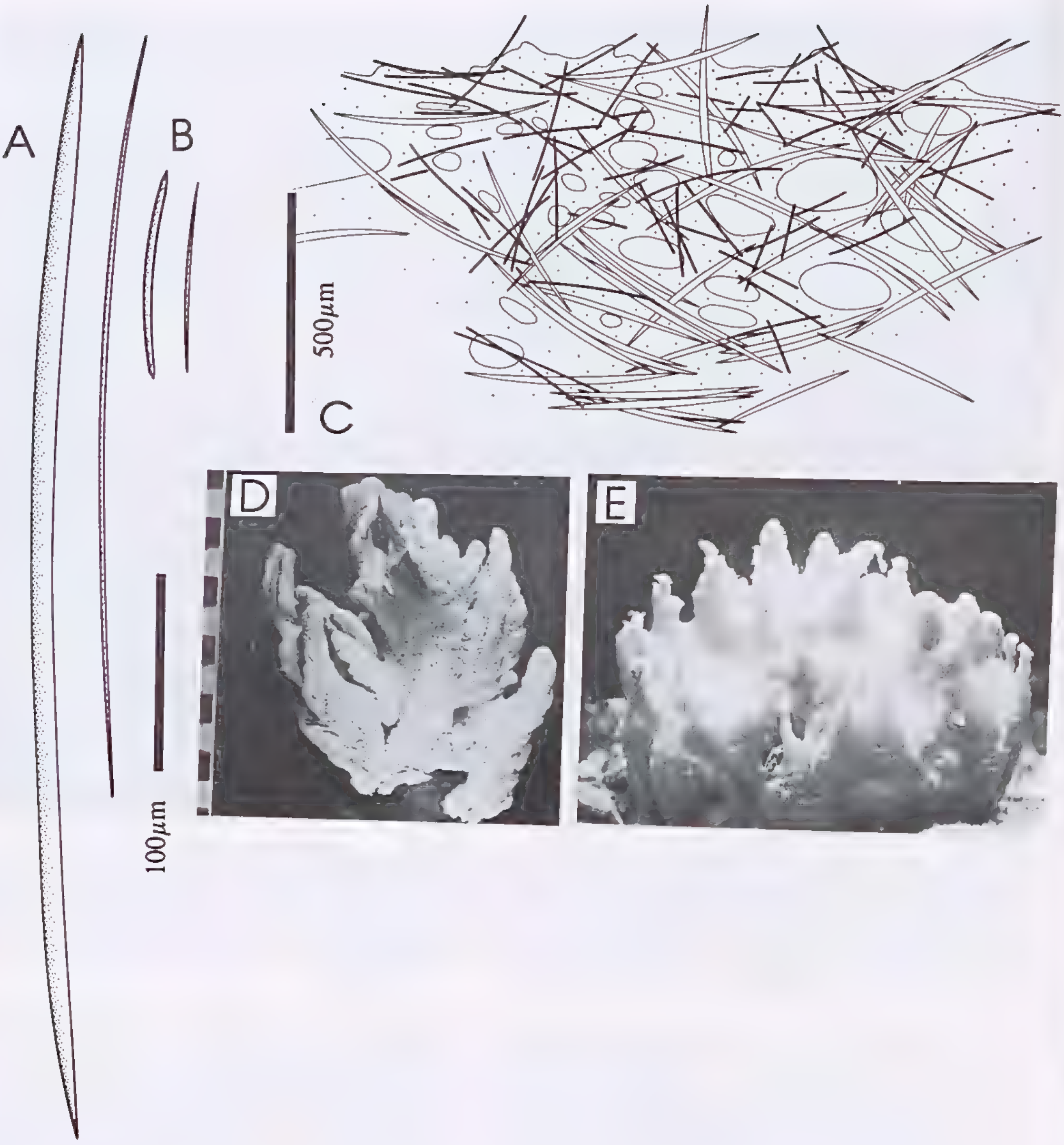

Fig. 28. *Halichondria stalagmites* (Hentschel). **A,** larger oxeas; **B,** smaller oxeas; **C,** peripheral skeletal structure; **D,** preserved specimen NTM Z3147; **E,** live subtidal specimen NTM Z1097.

Description. Growth form generally cushion-shaped base with fistulose apex, but specifically ranging from elongate, flattened palmate-branching (up to 160 mm high), with slightly flattened, spreading, lobate-digitate branches (up to 30 mm wide, 10 mm thick), slightly convoluted digits on lateral sides of sponge (presumed older specimens), to subspherical massive habits (up to 70 mm diameter), with tapering, blind fistule-like digits on upper surface, base attached to hard object (coral, shells) burrowing slightly into substrate (presumed younger specimens). Oscules discrete, conspicuous, approximately 3 mm diameter, found at base of larger fistules, or on lateral surface in flattened, branching specimens.

Colour. Orange-brown in life (Munsell 5YR 7/10-6/10), pale brown in ethanol.

Texture. Soft, compressible, spongy, easily torn. Fistules easily collapsable upon collection.

Surface. Fistules opaque, collagenous, slightly microconulose; surface even, unornamented between fistules; surface of burrowing mass generally membraneous and translucent through which cavernous choanosome visible.

Ectosomal skeleton. Thin tangential layer of unispicular tracts or multispicular tracts (two to three spicules abreast) composed of both smaller and larger choanosomal oxeas, without apparent localisation, bound together with granular collagen; spicules becoming plumose bundles in places, with oxeas occasionally protruding through ectosome, but mostly lying tangential to surface.

Choanosomal skeleton. All histological preparations contained cyanobacteria. Basal mass containing disorganised halichondroid unispicular reticulation of both larger and smaller oxeas, supported by occasional multispicular ('reticulate') tracts of larger oxeas; towards subectosomal region larger spicules producing more prominent multispicular bundles containing three to five spicules per tract; these becoming oriented perpendicular to surface near peripheral skeleton, occasionally protruding through it. Choanosomal region cavernous throughout, particularly in fistules, with lacunae between 100-300 µm in diameter in deeper choanosomal region of basal mass but larger (up to 500 µm) in subectosomal region of fistules. Collagen relatively abundant in mesohyl, in both basal mass and fistules, but no spongin fibres visible.

Spicules. Oxeas, fusiform, slightly telescoped or less frequently sharply pointed, in two size classes although not restricted to any particular location within skeleton (length I 335-(478.3)-675 µm, width 7-(11.4)-15 µm; length II 88-(171.2)-325 µm, width 2-(3.7)-5 µm).

Remarks. This species is apparently widely distributed throughout the Aru and Kai Islands of Indonesia, and is also relatively common throughout the Darwin region, although this is area appears to be its southernmost extent in distribution. The species is easily recognisable in the field by its orange-brown colouration and cushion-shaped fistulose growth form.

The northwest Australian population differs slightly from type material and the description of Hentschel (1912) in the extent to which the ectosomal skeleton is developed (represented only by a thin tangential peel in material described above, but more prominent in Hentschel's specimens), and the upper range of length of choansomal oxeas (675 µm long in present material whereas up to 1040 µm long in the Indonesian population). In all other respects, including the possession of telescoped points on spicules, northwest Australian and Indonesian populations are comparable.

Halichondria bergquistae sp. nov.
(Figs 29-30)

Type material. HOLOTYPE - QM G303351: East Point 'bommies', Darwin, NT, 12°24.5'S, 130°48.8'E, 10 m depth, 23 September 1993, coll. J.N.A. Hooper, L.G. Hobbs and B. Alvarez, SCUBA.

Distribution. East Point Aquatic Reserve, Darwin Harbour.

Habitat. Fringing coral reef, subtidal.

Description. Massive-lobate, bulbous-digitate (resembling a *Pseudaxinella*, family Axinellidae), 70 mm long, 55 mm wide, up to 45 mm thick. Oscules small (up to 3 mm diameter), conspicuous, discrete, with slightly raised membranous lip, mainly on apical surface of sponge.

Colour. Dark purple-mauve alive (Munsell 5RP 3/6); light brown in ethanol.

Texture. Firm, compressible.

Surface. Prominently hispid, conulose, shaggy in appearance, with an opaque, membranous, skin-like surface covering stretched between adjacent conules.

Ectosomal skeleton. Membranous, hispid with brushes of larger spicules protruding through surface, paratangential to it, supporting a sparse thin, tangential layer of smaller oxeas on external surface.

Choanosomal skeleton. Deeper parts of skeleton consisting of halichondroid reticulate architecture of single spicules or paucispicular tracts composed of larger oxeas. In subectosomal region spicule tracts more obvious, running predominantly longitudinally, ascending, becoming more radial, plumo-reticulate near periphery, with tracts composed mainly of larger oxeas and thinner oxeas also scattered throughout mesohyl. Spicule tracts uni- or paucispicular, loosely bound together with sparse collagen, without any obvious spongin fibres. Collagen in mesohyl light, nearly unpigmented. Choanocyte chambers ovoid, 40-50 µm diameter.

Spicules. Oxeas in two size classes: larger (predominantly choansomal) oxeas slightly curved at centre, tapering to fusiform sharp points (length 610-(797.2)-855 µm, width 15-(21.6)-32 µm); smaller (predominantly ectosomal) oxeas straight or slightly curved, fusiform

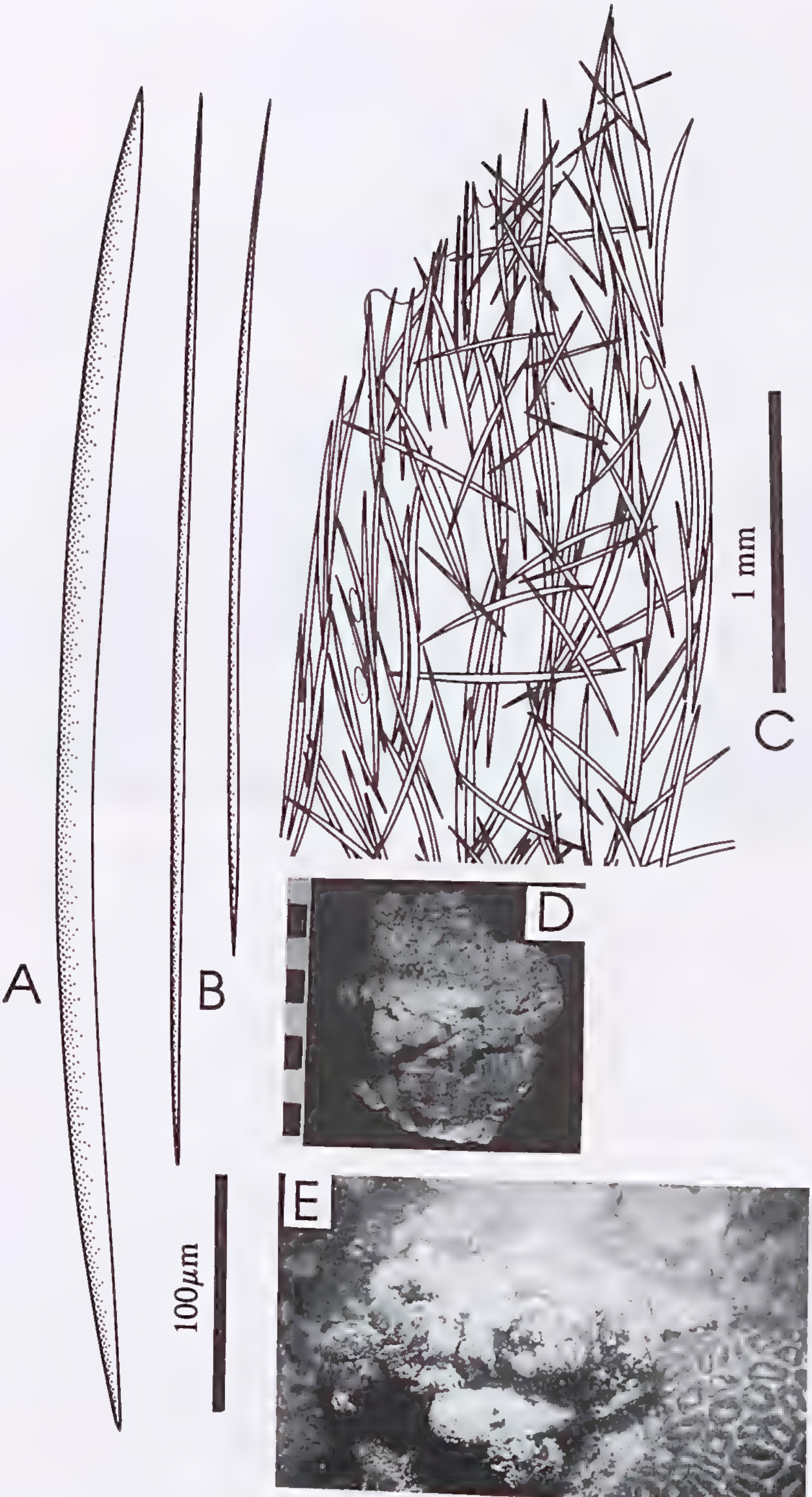

Fig. 29. *Halichondria bergquistae* sp. nov. **A,** larger (predominantly) choanosomal oxea; **B,** smaller (predominantly) ectosomal oxeas; **C,** peripheral skeletal structure; **D,** preserved holotype QM G303351; **E,** live subtidal holotype.

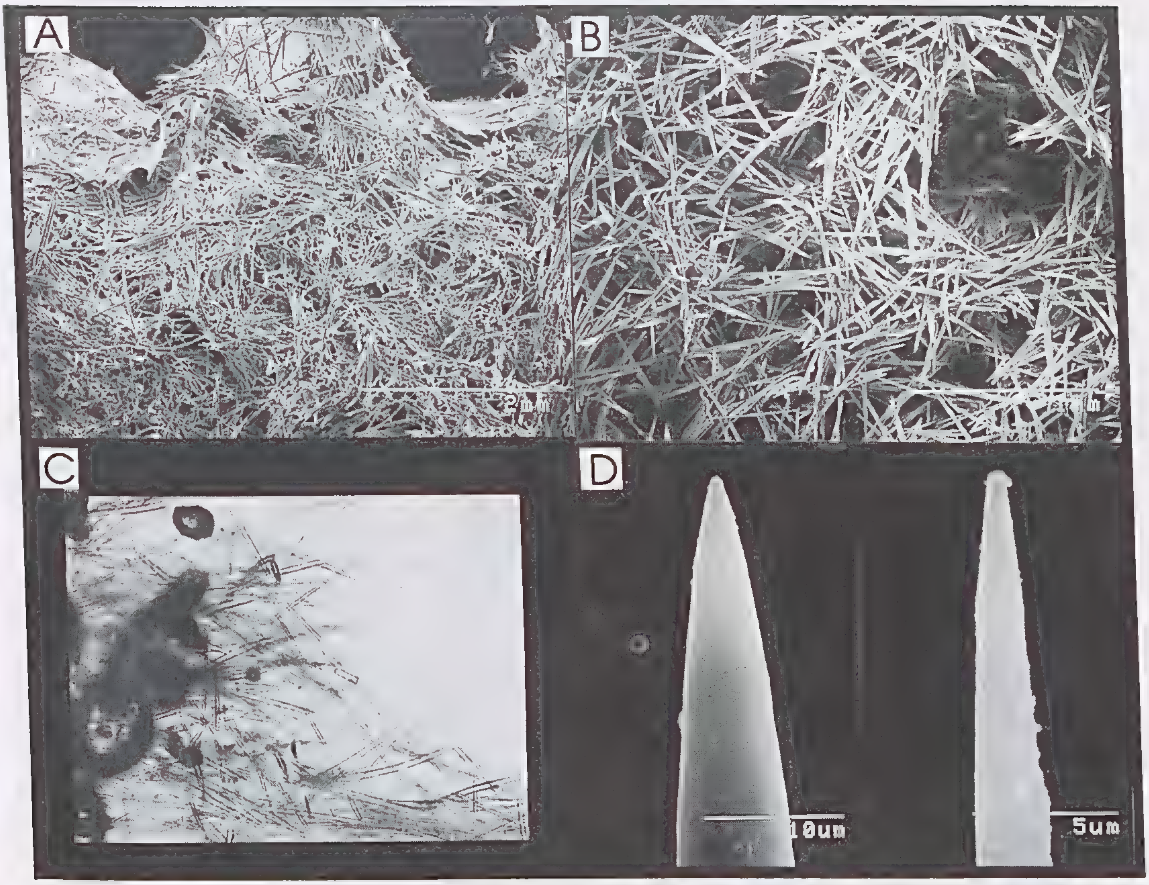

Fig. 30. *Halichondria bergquistae* sp. nov. Holotype QM G303351. **A,** perpendicular section through skeleton showing halichondroid reticulation of directionless pauci- and unispicular tracts, becoming more plumo-reticulate in subectosomal region, protruding through and supporting the thin tangential ectosomal crust; **B,** transverse section of ectosomal skeleton showing outer surface of sponge with protruding larger oxeas and sparse tangential smaller oxeas (with an ostium, upper right); **C,** light micrograph of section through peripheral skeleton showing plumo-reticulate subectosomal skeletal tracts; **D,** sharply pointed spicule terminations on both larger oxeas (left) and smaller oxeas (right).

sharply pointed (length 382-(509.5)-675 µm, width 5-(7.4)-12 µm).

Etymology. For Professor Patricia Bergquist, University of Auckland, for her unparalleled contributions to contemporary debate on sponge biology and systematics, and specific contributions to the taxonomic knowledge of Australasian sponges, including material from Darwin Harbour (Bergquist and Tizard 1967).

Remarks. This species was initially thought to belong to *H. melichlora* (Sollas) (from the Straits of Malacca (Sollas 1902) and Aru Island, Indonesia (Hentschel 1912)) based on descriptions of growth form, spicule geometry, possession of a slightly radial peripheral skeleton, and range of spicule sizes. But for several reasons this is not now accepted. Unfortunately, the holotype of *H. melichlora* has not yet been located, and both Sollas' (1902) and Hentschel's (1912) descriptions are fairly brief. However, from both these authors we know that *H. melichlora* has a massive growth form with flattened surface processes, a smooth unsculptured surface, a longitudinal central skeleton, a plumose subectosomal skeleton and a cavernous peripheral skeleton, and published spicule dimensions ranging from 350-960 x 30-42 µm for larger oxeas and 168-208 x – µm for smaller oxeas. By comparison, the growth form of *H. bergquistae* is lobate, bulbous-digitate, its surface is prominently conulose, shaggy (very reminiscent of *Pseudaxinella*), the choanosomal skeleton is halichondroid reticulate, becoming more radial towards the periphery, but without cavernous construction, and spicule dimensions are 610-855 x 15-32 µm for larger oxeas and 382-675 x 5-12 µm for smaller oxeas. On the basis of these differences it is warranted to recognise *H. bergquistae* and *H. melichlora* as distinct taxa.

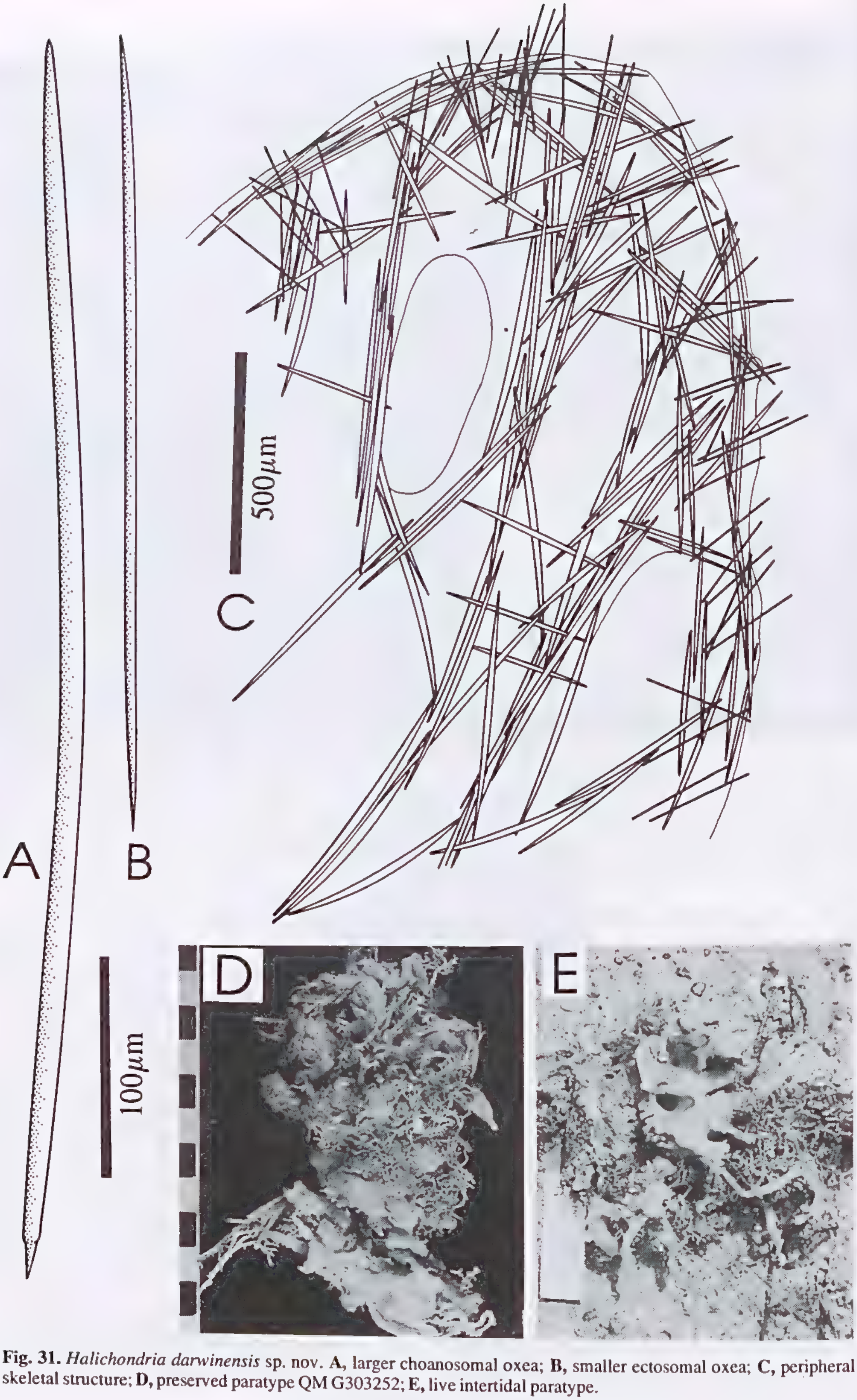

Fig. 31. *Halichondria darwinensis* sp. nov. **A,** larger choanosomal oxea; **B,** smaller ectosomal oxea; **C,** peripheral skeletal structure; **D,** preserved paratype QM G303252; **E,** live intertidal paratype.

Halichondria darwinensis sp. nov.
(Figs 31-32)

Type material. HOLOTYPE - NTMZ3205: Dudley Point Reef, East Point, Darwin, NT, 12°24.5'S, 130°48.0'E, intertidal, 25 September 1987, coll. N. Smit, by hand. PARATYPE - QM G303252: S of South Shell Island, East Arm, Darwin Harbour, NT, 12°29.8'S, 130°53.5'E, intertidal, 19 September 1993, coll. J.N.A. Hooper, L.J. Hobbs and B. Alvarez, by hand.

Distribution. South Shell Island and East Point Aquatic Reserve, Darwin Harbour, NT.

Habitat. Fringing coral reef, binding coral rubble substrate, growing on algae and dead coral; intertidal.

Description. Encrusting base, up to 15 mm thick, with stoloniferous, arborescent and bushy, fibrous, insubstantial digits on upper surface, with digits standing erect or meandering across substrate; digits up to 85 mm long, 6 mm diameter. Oscules small, discrete and conspicuous, up to 2 mm diameter, scattered on upper surface between upright surface processes.

Colour. Live colouration blue-grey on branch tips (Munsell 2.5B 8/2) and pale grey on base (5G 8/2); beige in ethanol.

Texture. Very soft, friable, easily torn.

Surface. Translucent, even, with fibrous and porous surface and underlying spicule tracts visible through ectosomal skeleton.

Ectosomal skeleton. Poorly developed, not detachable, thin tangential layer two to three spicules wide, composed mainly of smaller oxeas, overlaying larger choanosomal oxeas in paratangential subectosomal skeleton.

Choanosomal skeleton. Halichondroid reticulate skeleton of mainly longitudinal, multispicular tracts, with bundles of 5-10 oxeas ar-

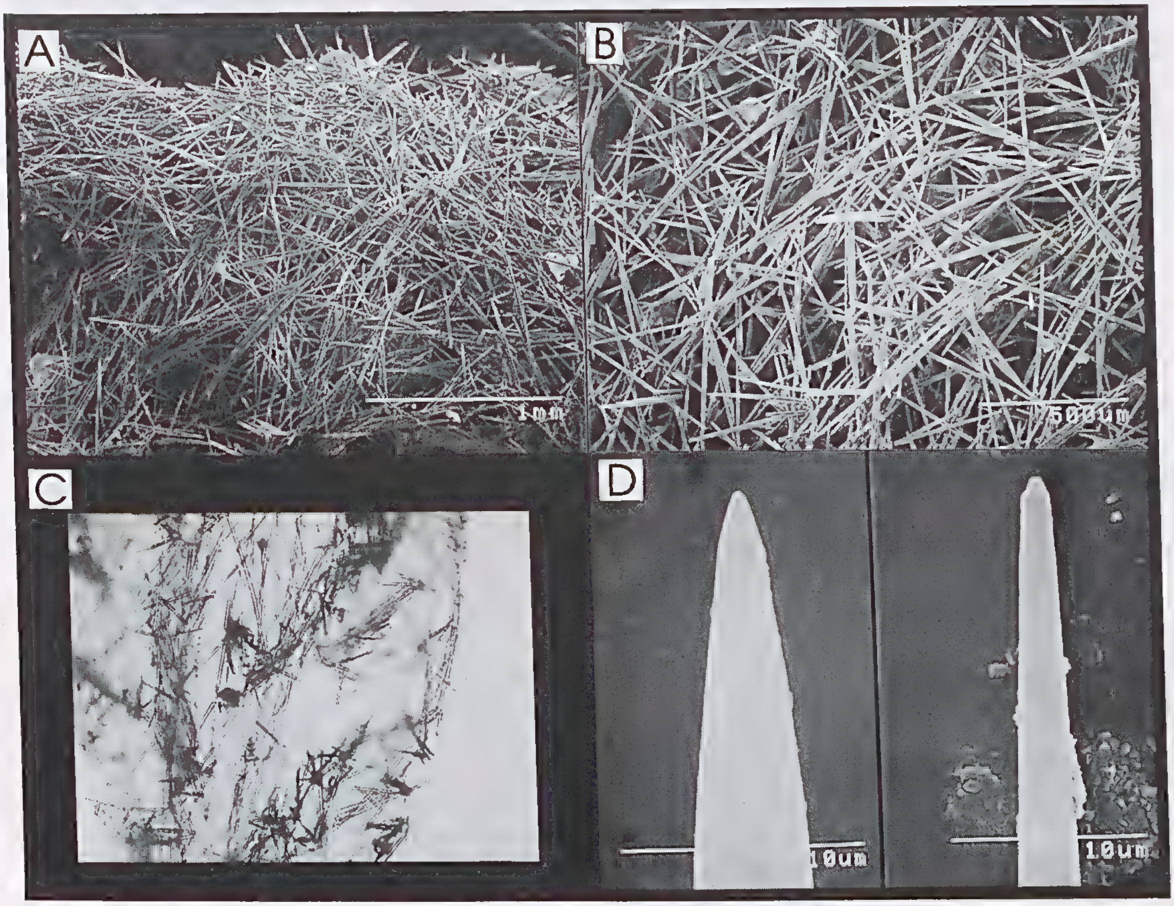

Fig. 32. *Halichondria darwinensis* sp. nov. Paratype QM G303252. **A,** perpendicular section through skeleton showing halichondroid unispicular reticulation and directionless multispicular tracts of the choanosomal skeleton; **B,** transverse section of ectosomal skeleton showing outer surface of sponge with a thin tangential unispicular layer of predominantly smaller spicules; **C,** light micrograph of section through choanosomal skeleton showing disorganised halichondroid multispicular tracts of larger spicules and thin, vestigial ectosomal skeleton (at right); **D,** sharply pointed spicule terminations on larger choanosomal oxeas (left) and abruptly telescoped (mucronate) points of smaller ectosomal oxeas (right).

ranged paratangentially in subdermal region supporting surface skeleton, and unispicular tracts dispersed between, both composed mainly of larger oxeas. Spongin fibres not evident. Collagen light to moderate in mesohyl, associated predominantly with spicule tracts.

Spicules. Oxeas in two sizes: thicker choanosomal oxeas straight or slightly curved at centre, with sharply pointed, tapering fusiform points (length 525-(622.0)-808 µm, width 6-(8.4)-12 µm); thinner ectosomal oxeas straight or rarely slightly curved, tapering fusiform, with prominently telescoped points (mucronate) (length 320-(392.2)-485 µm, width 1.5-(2.2)-3 µm).

Etymology. Named for the type locality, Darwin Harbour.

Remarks. *Halichondria darwinensis* is distinctive in its spicule size (having two categories of oxeas differentiated by their thickness moreso than their length, the shorter found mainly in the ectosomal skeleton, the larger found mainly in choanosomal tracts), spicule geometry (with sharply pointed choanosomal oxeas and prominently telescoped, mucronate points on ectosomal oxeas), skeletal structure (mainly longitudinal multispicular tracts of choanosomal oxeas, with single spicules dispersed between tracts producing a disorganised halichondroid-reticulate skeleton). In addition to these features seen in preserved material, the species also has distinctive field characteristics including a meandering stoloniferous growth form suited to growing on coral rubble, binding the substrate, a soft, easily torn consistency and a blue-grey live colouration. Relationships between *H. darwinensis* and other *Halichondria* are presently uncertain given that most of the field characters of this species have not been

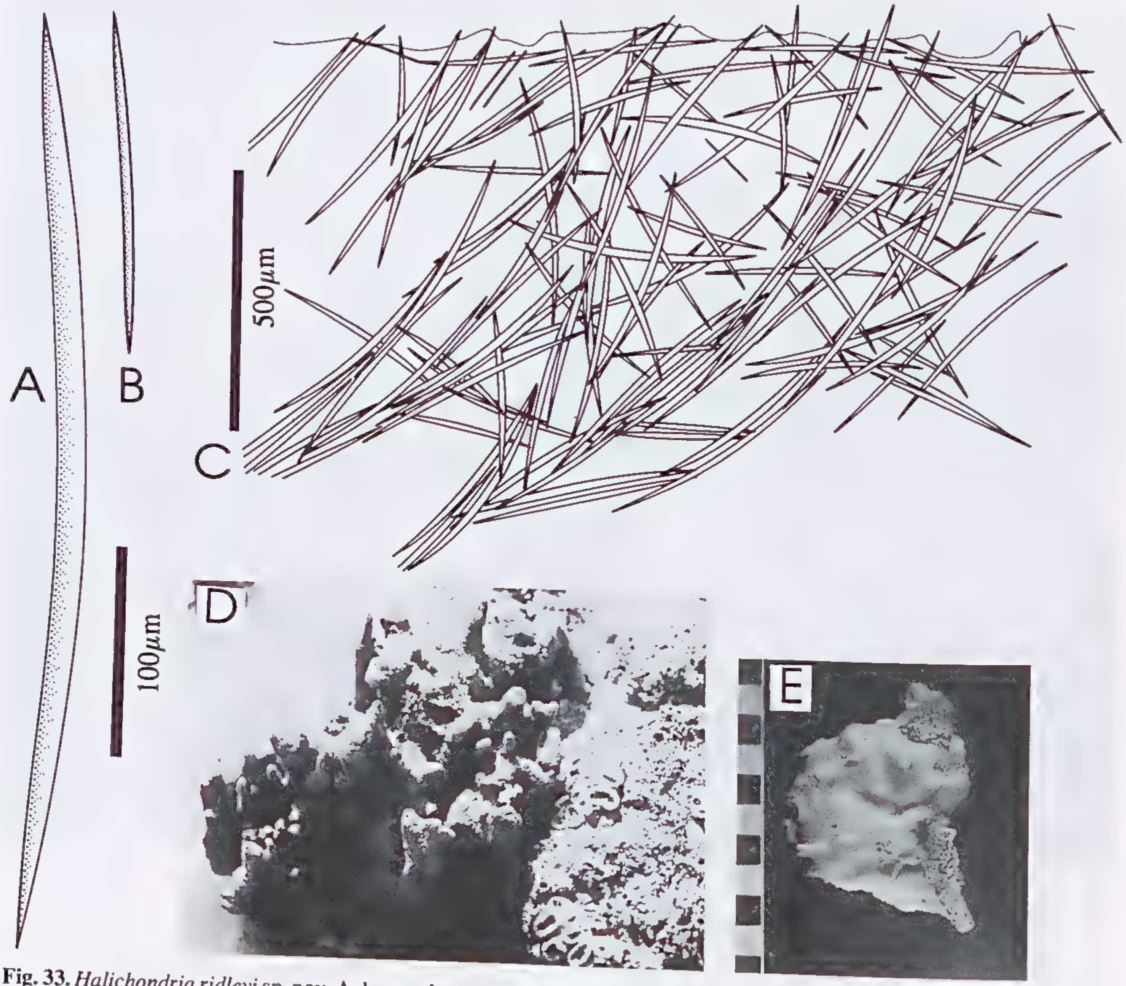

Fig. 33. *Halichondria ridleyi* sp. nov. **A,** larger choanosomal oxea; **B,** smaller ectosomal oxea; **C,** peripheral skeletal structure; **D,** live intertidal holotype QM G303309; **E,** preserved holotype.

well documented in other publications on Indo-west Pacific halichondriids.

Halichondria ridleyi sp. nov.
(Figs 33-34)

Type material. HOLOTYPE - QM G303309: Dudley Point Reef, East Point, Darwin, NT, 12°25.3'S, 130°49.0'E, intertidal, 20 September 1993, coll. J.N.A. Hooper and L.J. Hobbs, by hand.

Distribution. East Point Aquatic Reserve, Darwin Harbour.

Habitat. Dead coral and laterite rock reef; intertidal.

Description. Partly burrowing, excavating base, boring into dead coral, with massive erect, irregular surface processes, buttressed and fistulose, with fistules up to 54 mm long, 35 mm diameter at base. Oscules small, less than 2 mm diameter, scattered between surface processes.

Colour. Slightly mottled khaki dark yellow-brown exterior (Munsell 2.5Y 7/8-6/6) and beige interior alive; uniform beige-white in ethanol.

Texture. Firm, friable.

Surface. Opaque, hispid, even, unornamented.

Ectosomal skeleton. Thin, hispid, collagenous, non-detachable layer, with larger choanosomal spicules protruding through ectosome, erect or paratangential to surface, overlayed by smaller spicules lying tangential to surface, forming sparse tracts or occurring individually.

Choanosomal skeleton. Disorganised halichondroid, directionless tracts of single spicules throughout skeleton, composed mainly of larger oxeas, with tracts becoming only vaguely plumo-

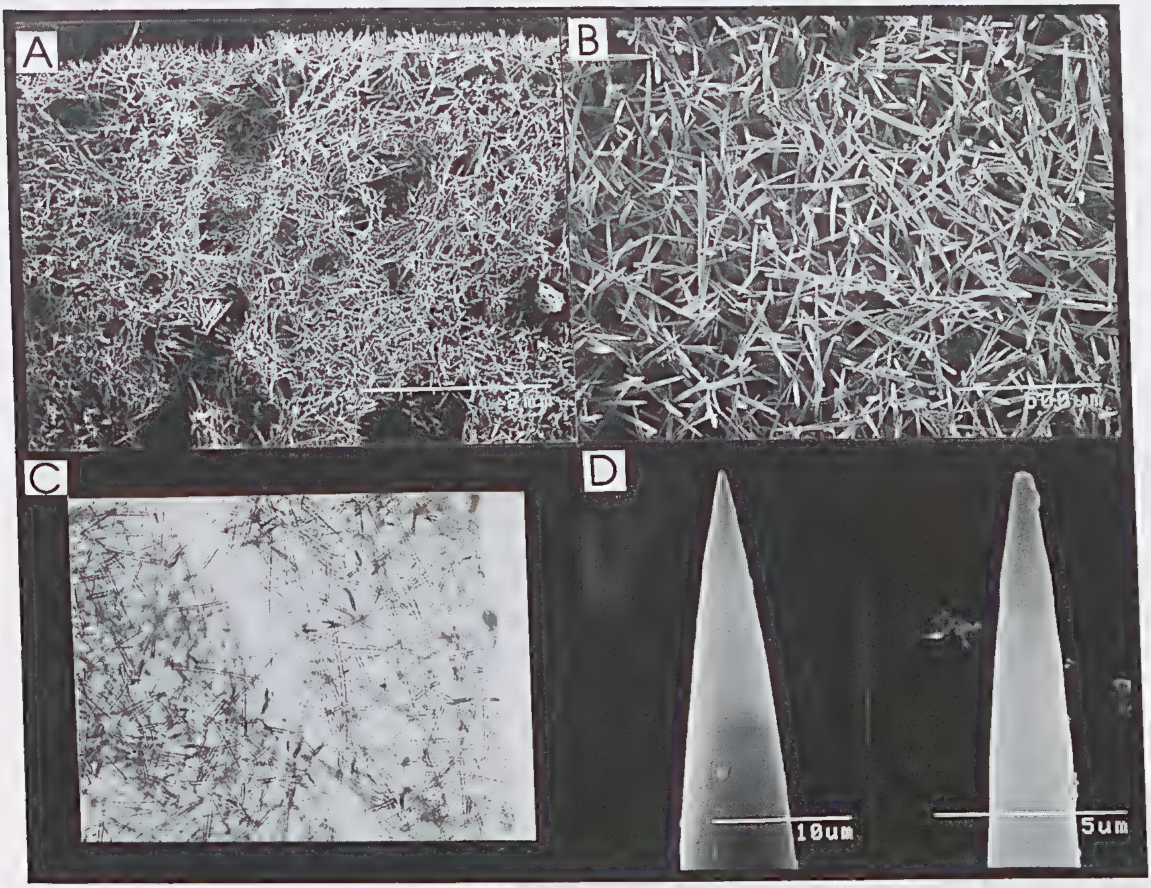

Fig. 34. *Halichondria ridleyi* sp. nov. Holotype QM G303309. **A,** Perpendicular section through skeleton showing halichondroid unispicular reticulation of directionless tracts throughout the choanosomal skeleton. **B,** Transverse section of ectosomal skeleton showing outer surface of sponge with protruding larger oxeas and tangential smaller oxeas. **C,** Light micrograph of section through peripheral skeleton showing directionless halichondroid uni- or paucispicular reticulation in choanosome, and vaguely plumo-reticulate subectosomal skeleton. **D,** Sharply pointed spicule terminations on both larger choanosomal oxeas (left) and smaller ectosomal oxeas (right).

reticulate in subectosomal region, forming erect or paratangential tracts ascending to (and protruding through) surface. Few multispicular tracts observed, meshes produced by skeletal reticulation small, ovoid, up to 200 µm diameter. Mesohyl collagen abundant, lightly pigmented and dispersed evenly throughout choanosome. Choanocyte chambers small, ovoid, up to 50 µm diameter.

Spicules. Oxeas in two size classes: larger choanosomal oxeas moderately or slightly curved at centre, with tapering fusiform, sharply pointed ends, occasionally stylote (length 305-(448.5)-565 µm, width 9-(16.3)-21 µm); smaller ectosomal oxeas straight or slightly curved, tapering fusiform, sharply pointed or blunt terminations (length 112-(164.2)-188 µm, width 4-(5.9)-8 µm).

Etymology. Named for Stuart O. Ridley, a pioneer of sponge taxonomy and author of the first comprehensive scientific treatise on Australian sponges, including material from Darwin Harbour (Ridley 1884).

Remarks. This species is similar to *H. mertoni* (Hentschel) from Aru Island (Hentschel 1912) in its burrowing, excavating base with robust, irregularly fistulose digits on the upper surface (unlike other fistulose species such as *H. tyleri* which have pencil-like digits). It differs from *H. mertoni* and other Indo-west Pacific *Halichondria* in having a khaki-brown live colouration, an even, unsculptured surface, a firm texture, a non-detachable tangential ectosomal skeleton, a choanosomal skeleton that is nearly completely disorganised halichondroid-reticulate throughout, including the peripheral skeleton (whereas many species of *Halichondria* have at least some skeletal organisation near the surface), and two size classes of oxeas (305-565 x 9-21 µm and 112-188 x 4-8 µm), the smaller distributed in the ectosomal skeleton. In *H. mertoni* the colouration is white, the fistules are prominently conulose and the outer surface is shaggy, the choanosomal skeleton has differentiated halichondroid central choanosomal skeleton and radial subectosomal skeleton, and there is only a single size class of (choanosomal) oxea (640-785 x 18-22 µm). Hentschel (1912) reported that there was no ectosomal skeleton in *H. mertoni* (in which case it would not belong to *Halichondria* at all), but one of the syntypes (SMF1608) does have a tangential ectosome although spicule sizes are undifferentiated.

Genus *Hymeniacidon* Bowerbank

Hymeniacidon Bowerbank, 1863: 1112.
Amorphilla Thiele, 1898: 44.
Stylohalina Kirk, 1909: 539.
Thieleia Burton, 1932a: 329.
Uritaia Burton, 1932b: 198.
Rhaphoxiella Burton, 1934: 554.
Rhaphidostyla Burton, 1935: 651.
Nailondra de Laubenfels, 1954: 182.

Type species. *Hymeniacidon caruncula* Bowerbank, 1864, by original designation (junior synonym of *Spongia perlevis* Montagu, 1818).

Diagnosis. Massive, encrusting or fistulose growth forms. Choanosomal skeleton poorly defined directionless spicule tracts with vaguely reticulate multispicular bundles and halichondroid criss-cross of single spicules between major tracts. Cavities (lacunae) often occurring in choanosomal and subetosomal regions, with vaguely ascending or oblique spicule tracts supporting ectosomal crust. Ectosomal skeleton thin tangential crust of single spicules or spicule bundles, usually detachable from surface. Megascleres exclusively styles and stylotes, usually of a single category.

Remarks. According to recent revisions (Van Soest *et al.* 1990; Diaz *et al.* 1991), *Hymeniacidon* is very similar to (and a sister taxon of) *Halichondria*. The two genera differ only substantially in having styles instead of oxeas, respectively (i.e. with the assumption that oxeas have been secondarily lost in *Hymeniacidon*). *Hymeniacidon* also has a characteristically more fleshy choanosomal structure, and its tangential ectosomal crust may be more poorly developed than in *Halichondria*, but there are few other significant differences between these genera.

There is some doubt about the proposed inclusion of *Stylotella* into synonymy with *Hymeniacidon* (Van Soest *et al.* 1990: 51). This doubt was implied by Hooper and Wiedenmayer (1994) in their recognition of *Stylotella* as a distinct genus from *Hymeniacidon*. This interpretation was based on characters taken from a single syntype of the type species, *Stylotella digitata* Lendenfeld, 1888 (AM G9152) from Port Jackson, NSW, which has a predominantly plumose subectosomal skeleton (best developed towards the periphery of the skeleton), a more disorganised halichondroid reticulate skeleton in the central portion of the choanosome, and lacks a tangential skeleton completely (having instead plumose bundles of styles protruding through the surface), unlike typical *Hymeniacidon*. These characters essentially agree with the redescription of *S. digitata* by Hallmann (1914: 349), although it is unclear which material his description was based. However, a redescription of a syntype of *Hymeniacidon agminata* Ridley, 1884 (BMNH 1881.10.21.347) also from Port Jackson, NSW, by Van Soest *et al.* (1990) (allegedly a senior synonym of *S. digitata*; Hallmann 1914), conflicts with this diagnosis, particularly in the fact that it does have "horizontally disposed spicules" in the ectosomal skeleton (Van Soest's *et al.* 1990: 55) and thus belongs to *Hymeniacidon*. (Van Soest *et al.'s* (1990) use of the term 'holotype' for this specimen is implicitly a lectotype designation). It is possible that *H. agminata* is not a synonym of *S. digitata*, contrary to the opinion of Hallmann (1914), but this must be ascertained by careful re-examination of the 25 or so type specimens of *S. digitata* and its alleged synonyms (see Hooper and Wiedenmayer 1994: 212).

Species of *Hymeniacidon* are widely distributed in both tropical and temperate waters of all oceans, including polar seas (see Diaz *et al.* 1991), recorded from shallow subtidal waters to depths exceeding 3500 m. Within the Indo-Australian region nine species have been recorded so far: *H. agminata* Ridley from eastern Australia (discussed above), *H. centrotyla* Hentschel, *H. fernandezi* Thiele, *H. kerguelensis* Hentschel and *H. torquata* Topsent from Macquarie Island, Subantarctic and Antarctic waters (Thiele 1905; Hentschel 1914; Koltun 1964, 1976), *H. halichondroides* (Thiele) from the south coast of NSW and Tasmania (Carpay 1986), *H. rigida* Dendy from Bass Strait, Vic. (Dendy 1897; Hallmann 1914), *H. gracilis* (Hentschel) and *H. suberitoides* (Brondsted) from the Java and Arafura Seas (Hentschel 1912; Brondsted 1934).

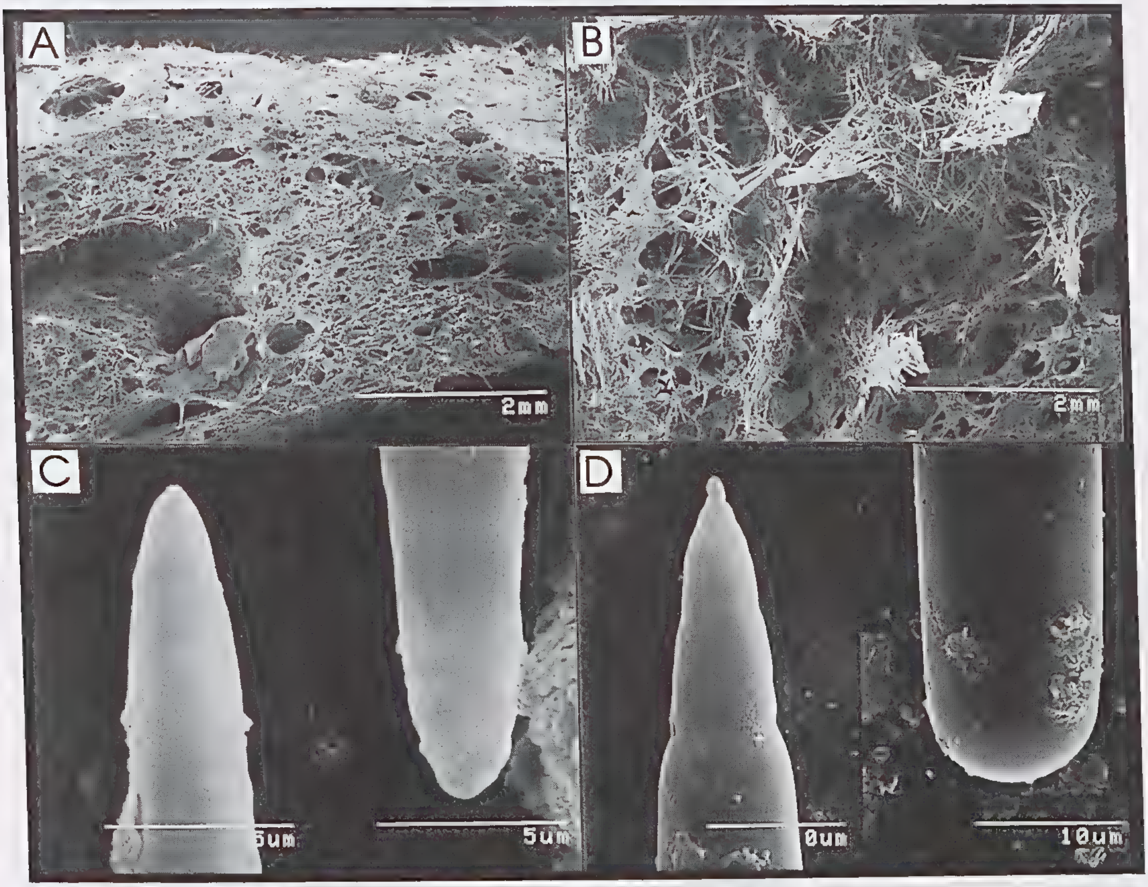

Fig. 35. *Hymeniacidon vernonensis* sp. nov. Holotype NTM Z4085. **A**, perpendicular section through skeleton showing disorganised unispicular halichondroid reticulation and cavernous, highly collagenous skeleton; **B**, transverse section of ectosomal skeleton showing the thin layer of collagen with scattered single spicules in halichondroid arrangement tangential to the surface; **C**, slightly telescoped points (left) and hastate base of smaller style (right); **D**, prominently telescoped point (left) and evenly rounded base of larger style (right).

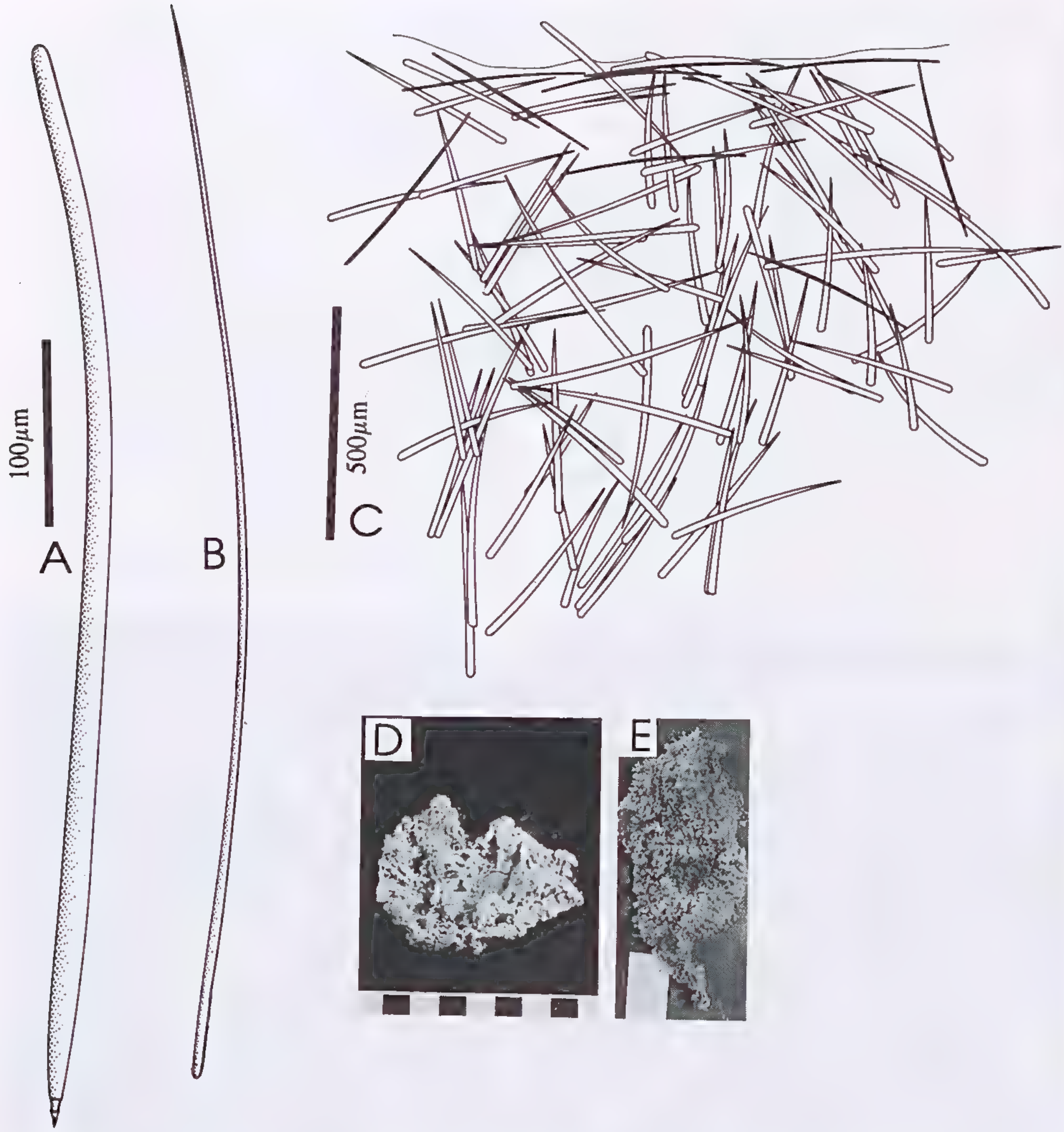

Fig. 36. *Hymeniacidon vernonensis* sp. nov. **A,** thicker style (predominantly in choanosomal skeleton); **B,** thinner style (predominantly in ectosomal skeleton); **C,** peripheral skeletal structure; **D,** preserved paratype QM G303570; **E,** live specimen (on deck) QM G303565.

Hymeniacidon vernonensis sp. nov.

(Figs 35-36)

Type material. HOLOTYPE - NTM Z4085 (fragment QM G303617): S of Northwest Vernon Island, NT, 12°03.9'S, 131°01.9'E, 25 m depth, 10 October 1993, coll. CCNT stn. 148 (1716). PARATYPE - QM G303570: SSE of Lyne Reef, Vernon Islands, NT, 12°07'S, 130°59'E, 30 m depth, 11 October 1993, coll. CCNT stn. 139 (1976), dredge.

Other Material. QM G303565: SSE of Lyne Reef, Vernon Islands, NT, 12°07'S, 130°59'E, 30m depth, 11 October 1993, coll. CCNT stn. 139 (1959), dredge.

Distribution. Known only from the Vernon Islands, Van Diemen Gulf, NT.

Habitat. Shell and rock substrate; subtidal, 6-30 m depth.

Description. Flat, plate-like, fan-shaped growth form, encrusting, following contours of substrate, with prominently shaggy and conulose surface, up to 90 mm long, 15 mm thick. Oscules small, up to 2 mm diameter, conspicuous, discrete, scattered over upper surface, with thin membraneous lip.

Colour. Yellow, yellow-brown, or orange-brown alive (in air) (Munsell 7.5YR 7/8 - 2.5Y 8/8), pale grey in ethanol.

Texture. Soft, compressible, easily torn.

Surface. Transparent outer surface, hispid, uneven, shaggy, conulose, with fibrous-membraneous appearance.

Ectosomal skeleton. Detachable, thin, membranous layer of granular pigmented collagen, with sparse layer of mostly thinner styles lying tangential to surface, usually in unispicular tracts and in disorganised halichondroid arrangement, and larger choanosomal styles protruding slightly through surface.

Choanosomal skeleton. Deeper regions of skeleton disorganised halichondroid reticulate, with single spicules or occasionally bundles of two or three, usually not forming tracts, consisting of mostly larger styles but also with thinner spicules dispersed between unispicular tracts. Subectosomal skeleton marginally more organised towards periphery, with choanosomal spicules generally ascending to surface, producing slightly plumose paucispicular tracts corresponding to position of surface conules. Spongin fibres absent, but collagen abundant in choanosomal mesohyl, containing large pigment granules. Choanosomal region irregularly cavernous, with large lacunae up to 1 mm diameter.

Spicules. Styles in two size classes: thicker styles (mostly found in choanosomal tracts) curved at centre, sinuous or rhabdose, fusiform, with evenly rounded bases, occasionally anisoxeote or mucronate, and prominently telescoped points or less often sharply pointed end (length 495-(584.4)-665 µm, width 12-(16.6)-22 µm); thinner styles (mostly found in tangential ectosomal skeleton) slightly curved at centre, with sharp pointed or slightly telescoped points, and tapering hastate rounded bases (length 252-(422.0)-565 µm, width 5-(6.4)-8 µm).

Etymology. Named for the type locality, Vernon Islands.

Remarks. These specimens were initially misidentified as *Stylotella flabelliformis* Hentschel, 1912, since both taxa have a prominently shaggy surface, flabellate growth form, essentially stylote megascleres forming disorganised, halichondroid reticulate skeletal structures only slightly more organised near the surface forming vaguely ascending spicule tracts, than in the centre of the skeleton. However, *H. vernonensis* has a tangential ectosomal skeleton composed of generally thinner styles than those inside the choanosomal skeleton (whereas the ectosome in *S. flabelliformis* is simply fleshy, membraneous, without tangential spicules but with protruding, vaguely erect choanosomal spicules piercing the surface). Its megascleres are also exclusively styles, many with telescoped points (whereas spicules of *S. flabelliformis* are either sharply pointed or modified to strongylote forms, never telescoped); the choanosome is fleshy, halichondroid-reticulate, with distinct horizontal and vertical spicule tracts throughout the skeleton (whereas in *S. flabelliformis* spicule tracts are essentially plumo-reticulate, vaguely ascending to the surface); and growth form is flattened fan-shaped, appearing to grow flat on the substrate (as opposed to erect, flabellate typical for *S. flabelliformis*).

Hooper and Lévi (1993b) recently redescribed *S. flabelliformis* from its Indonesian holotype as well as many other specimens from a number of localities throughout the Indo-west Pacific. They included it in the genus *Stylissa*, within the family Axinellidae, although both its generic and family assignments are still debatable, whereas the present species clearly belongs to *Hymeniacidon* in its spicule and skeletal characters.

Hymeniacidon gracilis (Hentschel)
(Figs 37-38)

Stylotella digitata var. *gracilis* Hentschel, 1912: 356-357, pl. 19, fig. 27.

Type material. HOLOTYPE - SMF 970: Between Meriri I. and Leer I., Aru Is, Arafura Sea, 6-10 m depth, 31 March 1908.

Other Material. NTM Z945: East Point 'bommies', Darwin, NT, 12°24.05'S, 130°48.0'E, 12 m depth, 13 September 1982, coll. J.N.A. Hooper, SCUBA. NTM Z987: same locality, 8 m depth, 26 October 1982. NTM Z883: Dudley Point Reef, East Point, Darwin, NT, 12°25.0'S, 130°48.04'E, 10 m depth, 31 August 1982, coll. J.N.A. Hooper, SCUBA.

Distribution. Aru Islands, Arafura Sea; Darwin Harbour.

Habitat. Rocky reef, sandy substrate; intertidal-subtidal depths.

Description. Thickly encrusting with erect, conulose lamellae forming thickly branching,

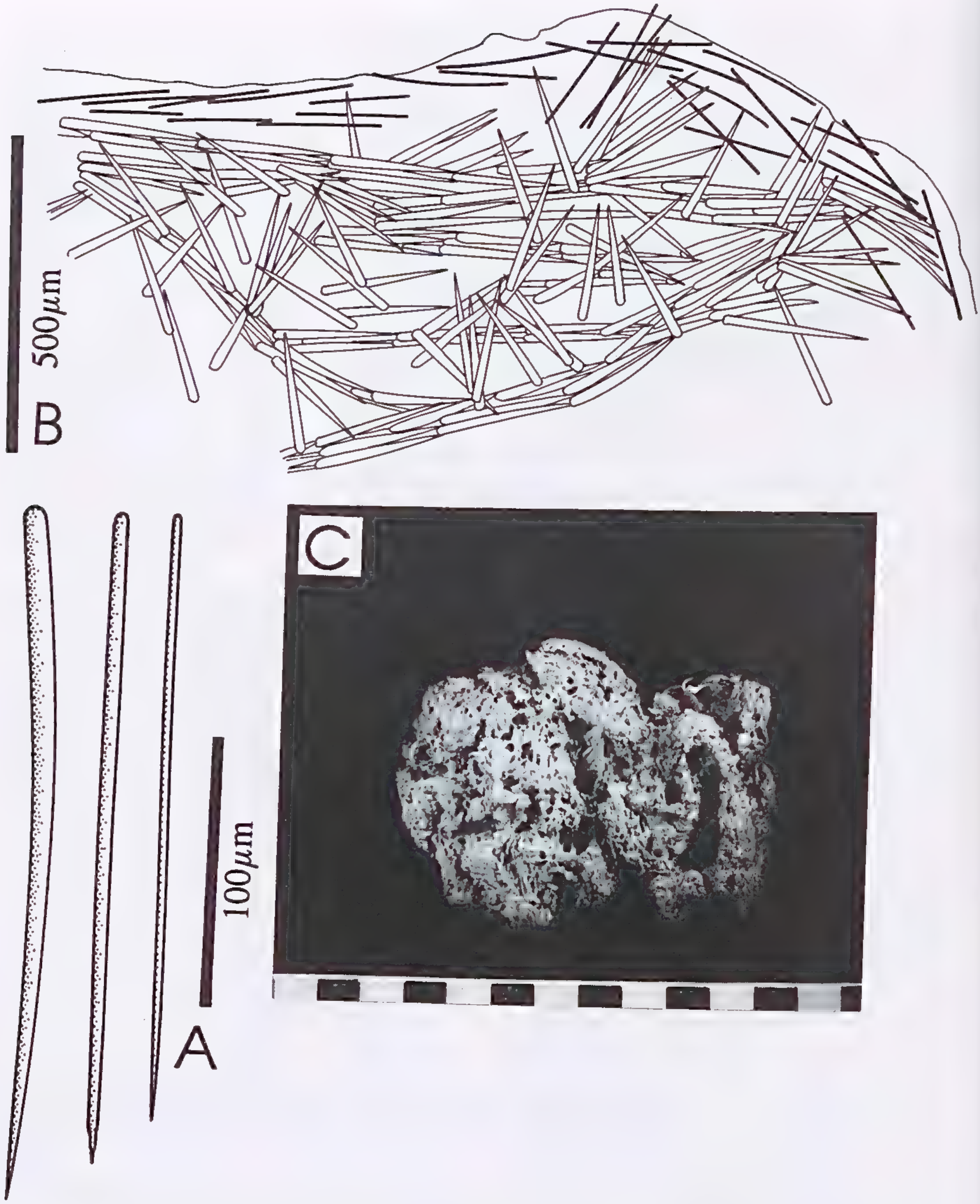

Fig. 37. *Hymeniacidon gracilis* (Hentschel). **A,** choanosomal styles; **B,** peripheral skeletal structure; **C,** specimen NTM Z945.

irregularly anastomosing, subspherical mass, up to 95 mm long, 55 mm diameter. Oscules small, less than 2 mm diameter, scattered over surface of lamellae.

Colour. Pale orange-red in life, (Munsell 10R 7/8), pink-beige in ethanol.

Texture. Soft, compressible, slimy.

Surface. Opaque, collagenous; uneven and papillose-conulose.

Ectosomal skeleton. Dense collagenous ectosomal skeleton, with single spicules or tracts of styles, 5-10 spicules abreast, aligned tangen-

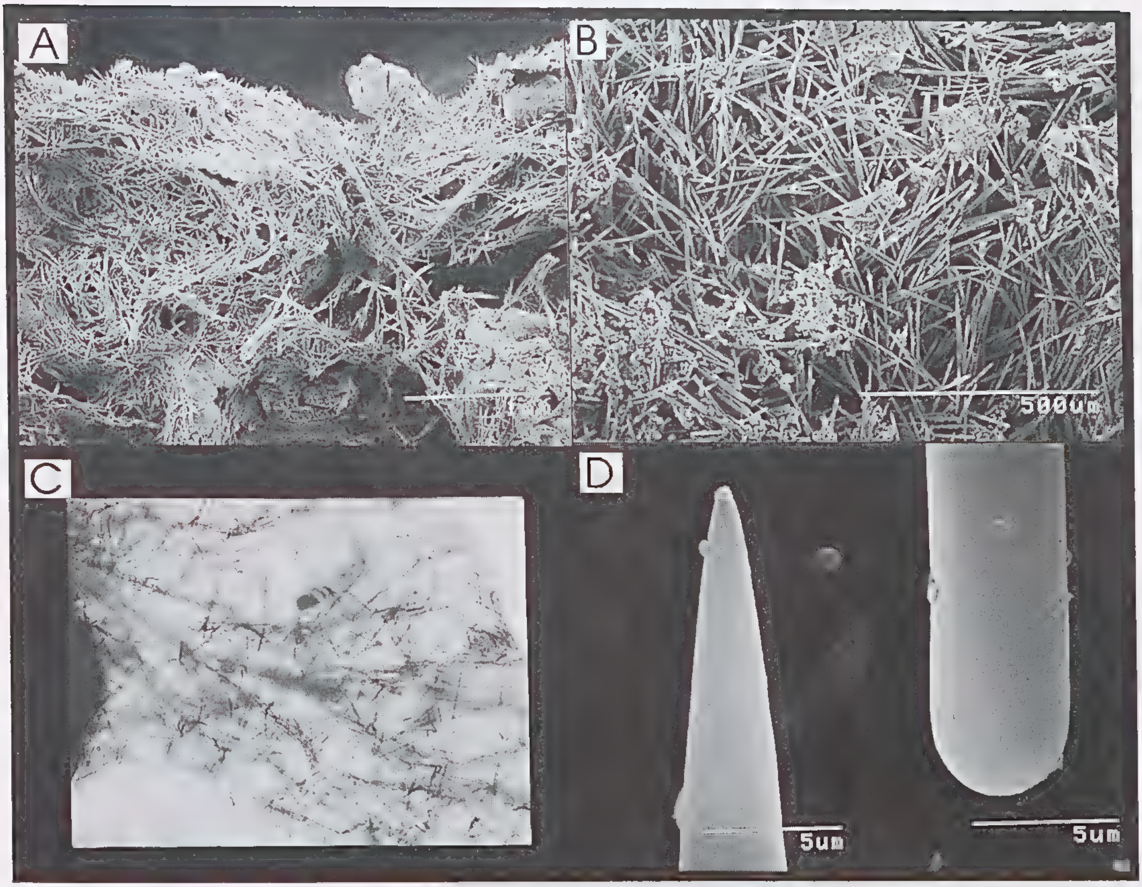

Fig. 38. *Hymeniacidon gracilis* (Hentschel). Specimen NTM Z945. **A,** perpendicular section through skeleton showing halichondroid reticulate choanosomal structure; **B,** transverse section of ectosomal skeleton showing outer surface of sponge with paratangential-plumose bundles of styles from the subectosomal skeleton and irregularly dispersed single or paucispicular tracts of styles lying tangential to the surface; **C,** light micrograph of section through peripheral skeleton showing plumo-reticulate development of the outer portion of subectosomal region; **D,** fusiform point (left) and evenly rounded base of style (right).

tial to surface; erect paucispicular plumose bundles of styles protruding through tangential layer, arising from deeper choanosomal skeleton.

Choanosomal skeleton. Interior of choanosome consists of single spicules or paucispicular bundles of two or three spicules abreast, forming partially organised, mostly halichondroid reticulate structure; spicule tracts becoming more organised towards surface, with distinct ascending multispicular plumose tracts in peripheral skeleton; paucispicular bundles protruding slightly through surface but only partially beyond collagenous layer. Collagen in choanosome less dense than ectosomal region and mostly associated with spicule bundles. In some specimens collagen appearing granular.

Spicules. Styles of single size class, straight or slightly curved, fusiform, sharply pointed, with evenly rounded bases (length 218-(251.2)-285 µm, width 2-(5.1)-8 µm).

Remarks. This species was originally described by Hentschel (1912) as a new variety (subspecies) of *Stylotella digitata* Lendenfeld, but there is very little resemblance in skeletal structure or growth form between these taxa and the Arafura Sea population is elevated here to full species rank. Spicule geometry, spicule dimensions and skeletal structure are comparable between southeast Indonesian and northwest Australian populations, whereas the holotype is substantially thinner than present material, with a concomitant reduction in the extent of development in the (organised portion) of the peripheral skeleton. The possession of a tangential ectosomal skeleton and a halichondroid-reticulate choanosomal skeleton, the latter only showing significant organisation near the periphery, indicates that the species belongs in *Hymeniacidon*.

Hymeniacidon hapalia sp. nov.
(Figs 39-40)

Type material. HOLOTYPE - NTM Z184: Dudley Point Reef, East Point, Darwin, NT, 12°°25.0'S, 130°49.01'E, 0.5 m depth, 13 September 1981, coll. J.N.A. Hooper and P.N. Alderslade, by hand. PARATYPE - QM G303414: N of South Shell I., Darwin Harbour, NT, 12°29.8'S, 130°52.9'E, 14 m depth, 25 September 1993, coll. J.N.A. Hooper and L.J. Hobbs, SCUBA.

Other Material. NTM Z272: Dudley Point Reef, East Point, Darwin, NT, 12°25.0'S, 130°49.01'E, 17 September 1981, coll. J.N.A.

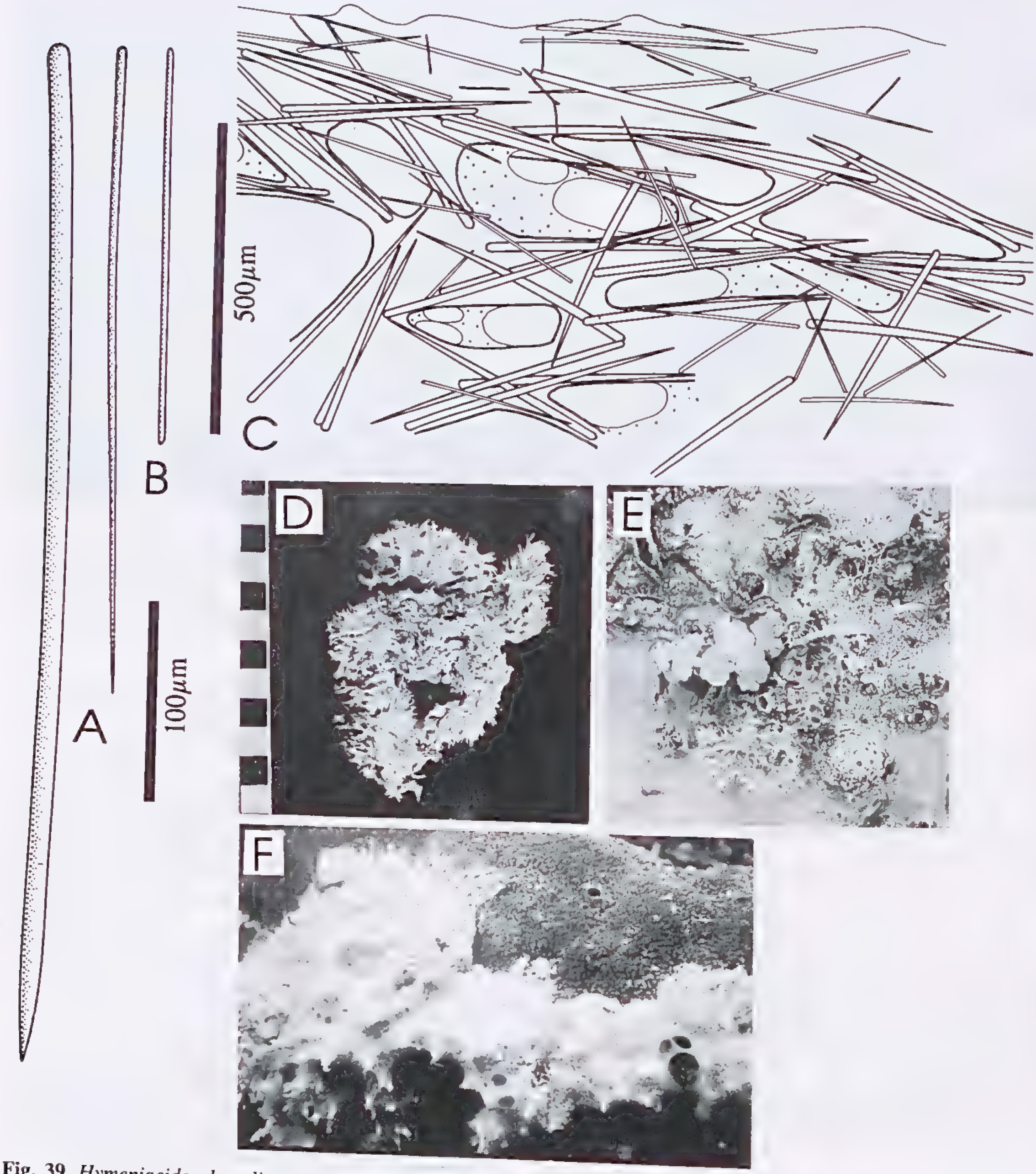

Fig. 39. *Hymeniacidon hapalia* sp. nov. **A,** larger styles; **B,** smaller strongylote styles; **C,** peripheral skeletal structure; **D,** paratype QM G303414; **E,** live intertidal specimen QM G303280; **F,** live subtidal holotype NTM Z184.

Hooper, by hand. NTM Z286, Z291: same locality, 1m depth, 18 September 1981, coll. J.N.A. Hooper, by hand. NTM Z2146: same locality, 27 September 1984, coll. J.N.A. Hooper, by hand. NTM Z2560: Fannie Bay reef, Darwin, NT, 12°24.50'S, 130°48.0'E, intertidal, 12 December 1985, coll. A.M. Mussig and C. Hood, by hand. NTM Z775: Channel Island, Darwin Harbour, NT, 12°33.0'S, 130°52.03'E, intertidal, 24 May 1982, coll. P.N. Alderslade, by hand. QM G303280: S of South Shell Island, East Arm, Darwin Harbour, NT, 12°29.8'S, 130°53.5'E, intertidal, 19 September 1993. coll. J.N.A. Hooper, L.J. Hobbs and B. Alvarez, by hand.

Distribution. East Point Aquatic Reserve, Fannie Bay Reef, Lee Point, Channel Island and South Shell Island, Darwin Harbour.

Habitat. Rocky reef, mudflats, fringing coral reef and coral pinnacles; intertidal-subtidal depths.

Description. Thickly encrusting, massive-bulbous, stoloniferous or elongate ridges, up to 30 mm thick, closely following contours of substrate. Oscules relatively large, conspicuous, discrete or multiple (sieve-plate), up to 5 mm diameter, usually on apex of surface ridges, between conules, surrounded by slightly raised membraneous lip.

Colour. Bright orange to dark orange alive (Munsell 10R 6/10 - 5YR 7/8), pale orange-brown in ethanol.

Texture. Soft, insubstantial, membraneous, easily torn, fragile (often disintegrating upon collection), producing clear mucus.

Surface. Long, sharply pointed or bifurcated, bushy, digitate and conulose surface processes scattered over surface, interconnected by fibrous ridges; surface opaque, prominently membranous, collagenous.

Ectosomal skeleton. Collagenous, membraneous, detachable ectosomal peel composed of granular, heavily pigmented collagen together with sparse, tangential or paratangential tracts or individual spicules, composed of both larger

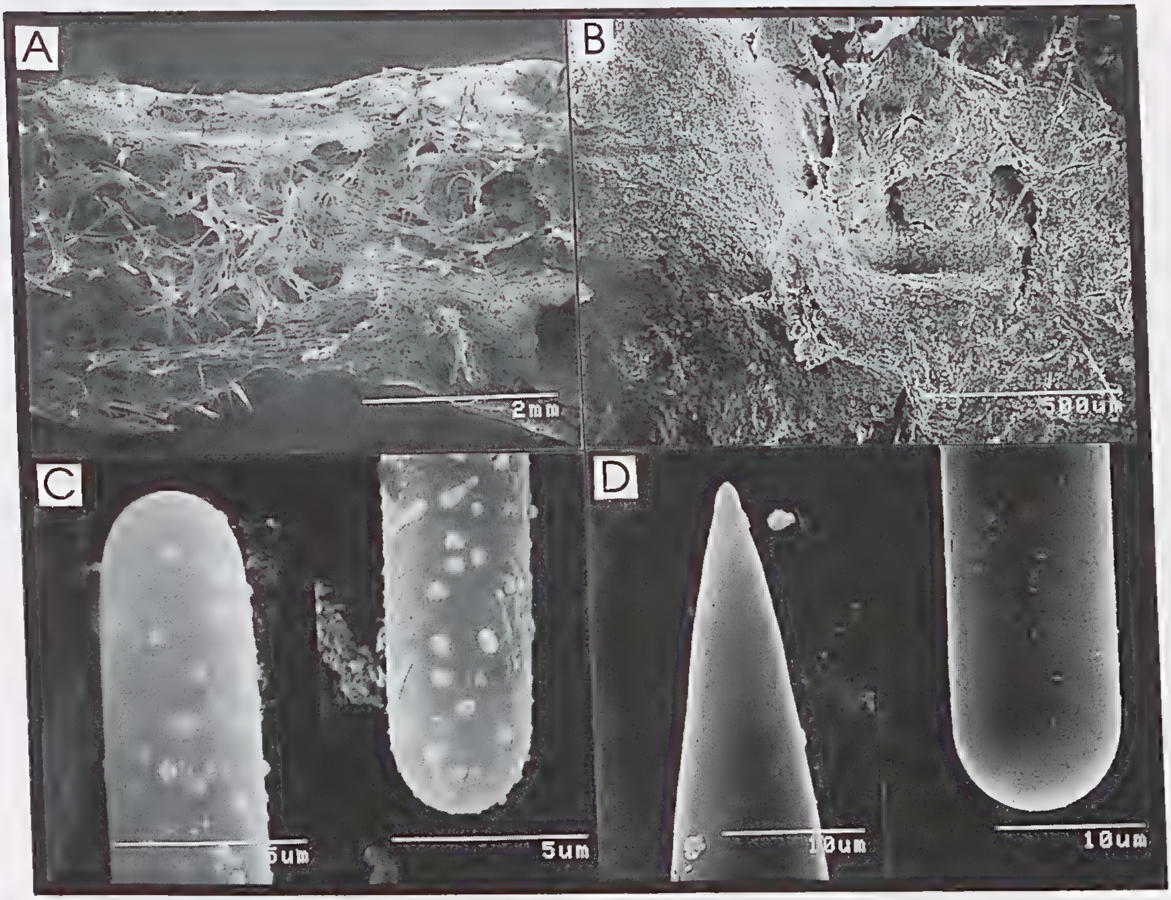

Fig. 40. *Hymeniacidon hapalia* sp. nov. Holotype NTM Z184. **A,** perpendicular section through skeleton showing irregular paucispicular reticulate fibres in subectosomal skeleton supporting collagenous ectosome; **B,** transverse section of ectosomal skeleton showing the aspicular collagenous outer surface; **C,** rounded, slightly asymmetrical ends of smaller strongylote styles; **D,** slightly telescoped point (left) and evenly rounded base of larger style (right).

styles and smaller strongylote styles; choanosomal fibres and spicules also protruding through surface only at surface conules.

Choanosomal skeleton. Deeper regions of choanosome predominantly collagenous, very granular; larger styles scattered individually throughout mesohyl and also forming paucispicular, irregular, directionless, halichondroid tracts, with both horizontal and vertically reticulate elements, bound together with abundant collagen. Subectosomal skeleton more obviously reticulate than central skeleton with pauci- and multispicular tracts easily visible. Collagen dominant over spicules throughout skeleton, particularly in periphery. Smaller strongylote styles also scattered within mesohyl, not confined to any particular region of skeleton, but generally not forming spicule tracts. Spicule meshes cavernous, up to 600 µm diameter in places.

Spicules. Spicules in two categories: larger styles straight or slightly curved at centre, fusiform, sharply pointed or with slightly telescoped points, with evenly rounded bases, some slightly rhabdose (length 375-(583.5)-1130 µm, width 3-(8.1)-15 µm); smaller strongylote styles straight, usually asymmetrical, with evenly rounded ends (length 182-(231.9)-275 µm, width 1-(2.1)-2.5 µm).

Etymology. Named for the soft, delicate, collagenous consistency, from *hapalus* (L.), soft to touch.

Remarks. This species is distinctive in the field, with dark orange colouration, prominently conulose fleshy surface, and very soft, relatively fragile, collagenous texture. It is predominantly intertidal, being a prominent member of the coral rubble community fringing the shores of Darwin Harbour, and when it is exposed to air during spring low tides it literally drips mucus (like many other tropical intertidal sponges and soft corals in this region), presumably with a function to protect the species from dessication during prolonged exposure to air. Although the species appears to be fragile to touch and collect, individuals exposed to air for many hours do not appear to undergo tissue necrosis or any other visible effects, unlike the widespread necrosis seen in many other subtidal species.

Hymeniacidon hapalia is unusual to the genus in having a predominantly collagenous ectosomal peel with only sparse tangential spicules or spicule tracts supporting the ectosomal peel. This paper-like ectosomal skeleton is nevertheless detachable, thus conforming to the strict definition of the genus *Hymeniacidon*. It was absent in some specimens, such as poorly fixed frozen samples, where the ectosome had presumably become detached from the remainder of the sponge prior to histology.

Hymeniacidon hapalia is also clearly unusual amongst other species of the genus in having smaller spicules of different morphology than the main structural megascleres. These strongylote spicules are clearly derived from styles as they have asymmetrical strongylote ends. They are not localised to any particular region of the sponge but are dispersed throughout the ectosomal and choanosomal regions, albiet sparsely.

Hymeniacidon hapalia should be compared to *Batzella corticata* (Thiele) and *Nailondra maza* de Laubenfels, both of which have styles together with modified strongylote styles (see brief redescriptions in Van Soest *et al.* 1990), but in both these species all spicules are approximately of equivalent length. It is possible that one of the genera synonymised under *Hymeniacidon* by Van Soest *et al.* (1990) should be resurrected for *H. hapalia*, such as *Rhaphoxiella* Burton (i.e. based on possession of modified stylote spicules as well as styles), or *Uritaia* Burton (with differentiated larger and smaller styles), or *Thieleia* Burton (with a predominantly collagenous ectosomal peel) - differences which Van Soest *et al.* (1980) considers to differ from *Hymeniacidon s.s.* only by degree - but such action is not warranted without a more in-depth study of the family, and for the present *H. hapalia* fits with a broad definition of *Hymeniacidon*.

The present species is also similar to *Stongylacidon intermedia* Burton, 1934, from the Great Barrier Reef (which de Laubenfels (1954) suggested belonged to *Ulosa*, Hooper and Wiedenmayer (1994) subsequently referred to *Batzella*, but is still poorly known). *Stongylacidon intermedia* is so far known only from the holotype, and has not yet been described from the living population. Nevertheless, its distinctive external appearance (massive, subspherical, with prominent, short digitate processes), skeletal structure (irregularly reticulate, branching, anastomosing tracts of megascleres surrounded by heavy collagen) and spicule geometry (strongyles and styles) are similar to those in *H. hapalia*, although spicule sizes are considerably different between the two species, 375-1130 x 3-15 µm and 182-275 x 1-2.5 µm for styles and strongyles, respectively, in *H. hapalia*; versus 140 x 3 µm for both strongyles and styles in *S. intermedia*. This latter species is *incertae sedis* until living populations are rediscovered.

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ENCHYTRAEIDS (OLIGOCHAETA: ANNELIDA) OF THE LOWER SHORE AND SHALLOW SUBTIDAL OF DARWIN HARBOUR, NORTHERN TERRITORY, AUSTRALIA.

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ABSTRACT

One new species of lower intertidal marine enchytraeid in *Randidrilus* Coates and Erséus, 1985, and two in *Grania* Southern, 1913, are reported from collections made in Darwin Harbour, Northern Territory, in the vicinity of the city of Darwin. Another species of *Grania* was poorly represented in the collections and so is not named, but a brief description is given for comparison in future studies. *Randidrilus darwinensis* sp. nov. is distinguished from its congeners by the absence of setae in segments anterior to IV and by spermathecae with saccate ampullae. This is the first record of the genus outside eastern North America. *Grania integra* sp. nov. and *Grania eurystila* sp. nov. both possess penial stylets, in the latter these are broad, strap-like, long and coiled, unlike those of any other species of the genus. *Grania integra* sp. nov. is not as distinctive but the combination of a spermatheca with a large rounded, saccate ampulla and a stylet in the penial apparatus is not previously recorded in the genus.

KEYWORDS: *Randidrilus*, *Grania*, marine enchytraeids, northern Australia, new species.

INTRODUCTION

The species of Enchytraeidae reported here were collected during the Sixth Marine Biological Workshop: the marine flora and fauna of Darwin Harbour, Northern Territory, Australia, July 1993. Only species found in the mid to lower intertidal, primarily on coarser, mixed sediments, are included in this contribution, representing all the species of *Randidrilus* and *Grania* that were collected during the workshop. There are no previous records of these or other enchytraeid genera along the coast of the Northern Territory.

Previous studies of the marine enchytraeids of Australia include three from Western Australia (Michaelsen 1907; Coates 1990; Coates and Stacey 1993) and one from the Great Barrier Reef off the coast of Queensland (Jamieson 1977). These account for reports of 12 species of *Grania* (more than one-third of all the described species of the genus) from the coastal areas of Australia, all endemic to the continent. There are no records for *Randidrilus* outside of the western Atlantic (Coates and Erséus 1985).

MATERIALS AND METHODS

The specimens described here include four species of enchytraeids found in mid to lower intertidal beach and coral rubble habitats. The specimens were found in 27 stations or samples taken at seven primary locations, four on the Cox Peninsula and three other locations around Darwin Harbour, near Darwin, Northern Territory. Salinity estimates in the field were made with a Spartan A366ATC hand refractometer.

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Collections were made by K. Coates, C. Erséus (stations designated by CE) and B. Healy (stations designated by BH). The general accession number of the collection is 1993-017, Royal Ontario Museum, Department of Invertebrate Zoology (ROMIZ). Marine enchytraeids of the genera *Grania, Randridrilus, Stephensoniella* and *Marionina* that were in samples collected by C. Erséus and B. Healy are held at ROMIZ; oligochaetes of other taxa from those samples are held by the Swedish Museum of Natural History or B. Healy, respectively (see Healy and Coates 1995; Erséus 1995). All holotypes and some paratypes are deposited in the Museum and Art Gallery of the Northern Territory, Darwin, Northern Territory, Australia (NTM). Other paratypes and reference material are deposited at ROMIZ.

Specimens were extracted from sediments in the field by a simple mechanical flotation method followed by sieving on a filter with pore size no larger than 350 µm. Mature specimens were sorted from the residue under a dissecting microscope, fixed in Kahle's solution (glacial acetic acid - 2 ml, 95% ethanol - 20 ml, formalin - 11 ml, made up to 100 ml with H_2O) and then preserved in 70% ethanol. Finally, specimens were stained with borax carmine and then mounted permanently in Canada balsam, following standard procedures for staining, destaining and dehydration.

Observations of whole-mounted specimens were made using both differential interference contrast and standard transmitted light microscopy. Drawings were made with the aid of a drawing tube; and measurements of specimens made and analysed using videomicroscopy with Jandel Video Analysis System (JAVA). Means and standard variations are reported, even for small sample sizes, in order to give some indication of the degree of variability among the specimens.

Abbreviations used in the figures. a, ampulla of spermatheca; **ap**, anterior penial gland; **c**, clitellum; **e**, ectal duct of spermatheca; **en**, ental duct of spermatheca; **es**, ?epidermal sac; **g**, gut; **gb**, glandular bulb; **i**, invagination at male pore; **js**, juvenile-type seta; **ls**, lateral seta; **m**, muscle band; **mg**, midventral "copulatory" gland; **mp**, male pore; **pg**, pharyngeal glands; **pp**, posterior penial gland; **ps**, posterior seta; **s**, spermatheca; **sf**, sperm funnel; **sg**, spermathecal gland; **sp**, spermathecal ectal pore; **sr**, sperm ring; **ss**, sperm sac; **st**, stylet; **vd**, vas deferens; **vs**, ventral seta.

LIST OF LOCALITIES AND STATIONS

The stations listed include only those at which enchytraeids of the genera *Randidrilus* and *Grania* were found. Stations at which other genera of enchytraeid were found, primarily upper intertidal, are given in Healy and Coates (1995) and collection sites of tubificid oligochaetes are given in Erséus (1995). Numerous sites were sampled for oligochaetes with negative results, and overall there were rather few stations, about one-third of the total sampled, at which significant numbers of enchytraeid specimens were found.

Locations 1-4. Cox Peninsula. *1. Southwest Beach,* 12° 26.5'S, 130° 47.0'E, and *Oak Point,* 12° 27.4'S, 130° 46.0'E. Station 1, beach, upper intertidal, protected flat, somewhat muddy, 5 July 1993, collector C. Erséus - *Randidrilus darwinensis* sp. nov. Station 11, beach near Mandorah Inn, upper mid-intertidal, coarse sand and pebbles, silt just under larger rocks, beach seepage, 7 July 1993, collector K.A. Coates - *Randidrilus darwinensis* sp. nov. Station 12, west side of reef at Oak Point, by beach seepage "creek" just above waterline, seepage salinity about 37‰, muddy sand, 7 July 1993, collector K.A. Coates - *Randidrilus darwinensis* sp. nov. Station 13, east side of reef at Oak Point, at mid-intertidal on beach above reef, seepage, blackened pebbles and sand, 7 July 1993, collector K.A. Coates - *Grania* sp. Station BH62, first mangrove opening south of Mandorah Inn, dry bed of creek, only reached by spring tides, moist sand under dry mangrove leaves, fine to medium sand, 14 July 1993, collector B. Healy - *Randidrilus darwinensis* sp. nov. Station 55, beach, near Oak Point reef, silty sand sediments, black/grey at about 5 cm depth, 18 July 1993, collector K.A. Coates - *Randidrilus darwinensis* sp. nov.

2. Woods Inlet, 12° 27.5'S, 130° 45.8'E. Station CE-7, outer end of Inlet, south of reef at Oak Point, lower intertidal sand, gravel and rubble, 7 July 1993, collector C. Erséus - *Randidrilus darwinensis* sp. nov. Station CE-34, outer part of Inlet, about 1 km south of Mandorah Inn, large tidal creek paralleling beach, sand, gravel and shell, 14 July 1993, collector C. Erséus - *Grania eurystila* sp. nov. Station CE-39, outer part of Inlet, large tidal creek paralleling beach, behind dune, sand, gravel and shell, with some green algae on surface of sediments, 16 July 1993, collector C. Erséus - *Grania eurystila* sp. nov. Station CE-

40, outer part of Inlet, intertidal rock pool created by a large cement ring buried in sand, near tidal creek, 16 July 1993, collector C. Erséus - *Grania eurystila* sp. nov.

3. *West Point,* 12° 26.2'S, 130° 46.0'E. Station 36, reef pools low in intertidal, with coarse mineral sands, rounded laterite pebbles and silt, salinity 37‰, 11 July 1993, collector K.A. Coates -*Randidrilus darwinensis* sp. nov. Station 37, shell and quartz sand, in shallow pools at low water, about 2.2 m above MLW, salinity 37‰, 11 July 1993, collector K.A. Coates - *Randidrilus darwinensis* sp. nov., *Grania integra* sp. nov. Station 38, coarse shell and coral rubble from crevices just above low water, as above, with fine silt covering surface of sediments, 11 July 1993, collector K.A. Coates - *Randidrilus darwinensis* sp. nov. Station 39, outer point of reef, coarse shell and coral rubble with silt, at low water line, 2.2 m above mean low water, 11 July 1993, collector K.A. Coates - *Randidrilus darwinensis* sp. nov. Station CE-22, lower intertidal crevice with sand, gravel and pebbles under rocks, 11 July 1993, collector C. Erséus - *Randidrilus darwinensis* sp. nov., *Grania integra* sp. nov. Station 51, inside reef, in pockets of coarse sand, shell, pebble sediments with silt, near daily lower high water line, about 4.8 m above mean low water, patchy reduction of sediments to within 1.5 cm of surface, wet, 16 July 1993, collector K.A. Coates - *Randidrilus darwinensis* sp. nov. Station 52, coarse shell and gravel at about mid-upper tide level, above reef, among boulders and broken bedrock, 16 July 1993, collector K.A. Coates - *Randidrilus darwinensis* sp. nov.

4. *Imaluk Beach,* 12° 25.5'S, 130° 44.0'E. Station 33, rocky reef at east end of beach, pool in rocks with stony corals and blue compound ascidians, 10 July 1993, collector K.A. Coates - *Randidrilus darwinensis* sp. nov., *Grania integra* sp. nov.

5. *East Arm,* intertidal shoal, 12° 29.4'S, 130° 53.7'E. Station 19, rocky island off shoal, 200 m west of boat ramp, near North Shell Island, coarse sand and shell, sheltered from sea, just above low tide level, salinity of pooled water in sediments 40‰, 8 July 1993, collector K.A. Coates - *Randidrilus darwinensis* sp. nov. Station CE-10, 200 m west of boat ramp, near North Shell Island; rocky tidal flat, lower intertidal, coarse sand between boulders, 8 July 1993, collector C. Erséus - *Randidrilus darwinensis* sp. nov., *Grania eurystila* sp. nov. Station CE-11, at end of mangrove "beach", opposite North Shell Island, lower intertidal, coarse red shelly sand, among large rocks, 8 July 1993, collector C. Erséus - *Randidrilus darwinensis* sp. nov.

6. *Rapid Creek,* 12° 23-25'S, 130° 51.0'E. Station CE-16, intertidal flat, mid tide level, in creek bed, tidal seawater, coarse sand and gravel with some filamentous green algae overgrowing, 9 July 1993, collector C. Erséus - *Grania integra* sp. nov.

7. *Lee Point,* 12° 20.0'S, 130° 53.0'E. Station 9, north end of Point, coarse red pebbles with sand and silt, among boulders in areas of live corals, about 1 m above low water, 6 July 1993, collector K.A. Coates - *Randidrilus darwinensis* sp. nov. Station 10, north end of Point, mid-upper beach, depressions in sand and small pools of water, salinity 51‰, fairly coarse clean sand and shell, among rock outcrops, iron nodules, 6 July 1993, collector K.A. Coates - *Randidrilus darwinensis* sp. nov. Station BH5, coarse sand in gullies and crevices among rocks on lower shore, 6 July 1993, collector B. Healy - *Randidrilus darwinensis* sp. nov. Station 63, north reef at Lee Point beach, coarse sediments under rock ledges and sheltered behind boulders, some pebbles and shell, sediments not reduced at maximum depth sampled, at low tide level, 20 July 1993, collector K.A. Coates - *Randidrilus darwinensis* sp. nov., *Grania integra* sp. nov. Station 65, north reef, coarse sediments between rocks, with some reduced organic matter, near low water, 20 July 1993, collector K.A. Coates - *Randidrilus darwinensis* sp. nov.

SYSTEMATIC ACCOUNT

Family Enchytraeidae
Randidrilus Coates and Erséus, 1985

Randidrilus Coates and Erséus, 1985: 104.

Lumbricillus Ørsted, 1844 (part); - Lasserre, 1971: 445, 448, 450.

Type species. *Lumbricillus codensis* Lasserre, 1971.

Amendments to diagnosis. The original diagnosis of the genus indicated that lateral setae were lacking and ventral setae were usually present in segment II. The inclusion of the new species *Randidrilus darwinensis* requires that this be modified as in this species lateral setae are present in postclitellar segments and ventral setae are present only from V, rather like *Grania*. The new species also has rings of sperm in the spermathecal ampulla, which appear to be closely associated with the tissue of the wall (?embedded), unlike previously described species of the genus.

Remarks. The genus has not been recorded previously outside of the northeast coast of the United States. In the North American locations, specimens were found only in coarse to medium sediments of the shallow subtidal to depths of 58 m (Coates and Erséus 1985), but not in intertidal habitats as at Darwin. The large tidal range, up to 8 metres, in the area of Darwin may explain the occurrence of the genus in these recent intertidal collections. Salt water seepage was observed to continue in coarse sediments throughout periods of exposure so that salinities and temperatures may not have varied significantly from those occurring in shallow subtidal habitats in the Darwin area. However, the new species was also found in intertidal sediments with overlying pooled water of salinities up to 57‰ and near ambient air temperatures, about 35°C.

The large tidal range leads to significant tidal currents that cause instability in unprotected coarser, well-sorted, sediments. This probably accounts for the number of "likely" habitats that were sampled but were not found to harbour enchytraeids. Specimens of *Randidrilus* were found primarily in sheltered deposits among boulders, corals and coral rubble near the lower intertidal, which would be affected most by the slower ebbing and flooding rates at tidal extremes and little influenced by wave action.

Randidrilus darwinensis sp. nov.
(Fig. 1)

Type material. HOLOTYPE - NTM Wo.0084, station 51, Cox Peninsula, West Point, 12° 26.2'S, 130° 46.0'E, inside reef, in pockets of coarse sand, shell, pebble sediments with silt, about 4.8 m above mean low water; patchy reduction of sediments to within 1.5 cm of surface, wet, 16 July 1993, collector K.A. Coates. PARATYPES - type location, 1 immature, ROMIZ I2457, and 5 mature specimens (three at NTM Wo. 0085, Wo.0086, Wo.0087; and two at ROMIZ 12458).

Other material. Station 1, 2 specimens, station 9, 4 specimens, station 10, 1 specimen, station 11, 2 specimens, station 12, 1 specimen, station 19, 4 specimens, station 33, 3 specimens, station 36, 7 specimens, station 37, 14 specimens, station 38, 5 specimens, station 39, 12 specimens, station 52, 15 specimens, station 55, 1 specimen, station 63, 1 specimen, station 65, 1 specimen, station CE-7, 6 specimens, station CE-10, 4 specimens, station CE-11, 1 specimen, station CE-22, 7 specimens, station BH5, 16 specimens, station BH62, 2 specimens. Including mature and partially mature specimens.

Description. Length 6.7-10.5 mm (n=6, $\bar{x}$=8.7, s=1.5), diameter at V, 132-149 mm (n=5, $\bar{x}$=0.140, s=0.007), 142-157 mm (n=5, $\bar{x}$=0.148, s=0.006) at clitellum (Fig. 1A), (29) 32-58 segments (n=68, $\bar{x}$=49.5). Ventral setae (Fig. 1B) from V, setae of V usually relatively small, other ventral setae 50-85 mm (n=12, $\bar{x}$=71, s=10) long, midventral setae of similar average length, posterior ventrals just shorter; lateral setae (Fig. 1C) from XVI-XXI, most frequently XIX or XX, length of midlateral setae 46-61 mm (n=13, $\bar{x}$=53, s=4), posterior lateral setae just longer, 49-68 mm (n=13, $\bar{x}$=58, s=5). As individuals mature, juvenile setae (Fig. 1C-D) are replaced by robust, broad ended setae of an adult form (Fig. 1B-C); this change seems to progress more or less from anterior to posterior segments, although in the younger, more posterior segments, the setae are robust even in the less mature specimens examined (these segments only develop after the worm has reached a certain level of sexual maturation). Thus replacement of small setae in partially mature individuals is most obvious ventrally and laterally in segments from about VIII through XXV; setae of V (see Fig. 1B) remain smaller than those of VI through XI. Spermathecal pores paired, lateral about one-third of the way back in segment V (Fig. 1A). Clitellum extending over XII and XIII, granular gland cells not well-developed ventrally between male pores. Male pores (Fig. 1A) lateroventral just posterior to mid XII; female pores posterior to 12/13, in line of male pores. Large midventral gland with epidermal papilla in XIV. Pharyngeal glands with dorsal, intraseptal lobes at 4/5, 5/6 and 6/7, not united dorsally, ventral lobes extending through V and VI and small lobes anterior to 4/5 (Fig. 1A). Nephridia not seen in preserved material. Dorsal blood vessel origin between XVI and XIX. Sperm funnel collar equal funnel width; sperm funnel length about 3-5 times width (Fig. 1A), length 207-266 mm (n=5, $\bar{x}$=227, s=23), width 47-71 mm (n=5, $\bar{x}$=56, s=9), funnel usually confined to XI and XII. Vas deferens diameter about 5-8 mm (n=5, $\bar{x}$=6.4, s=1.2), more or less regular

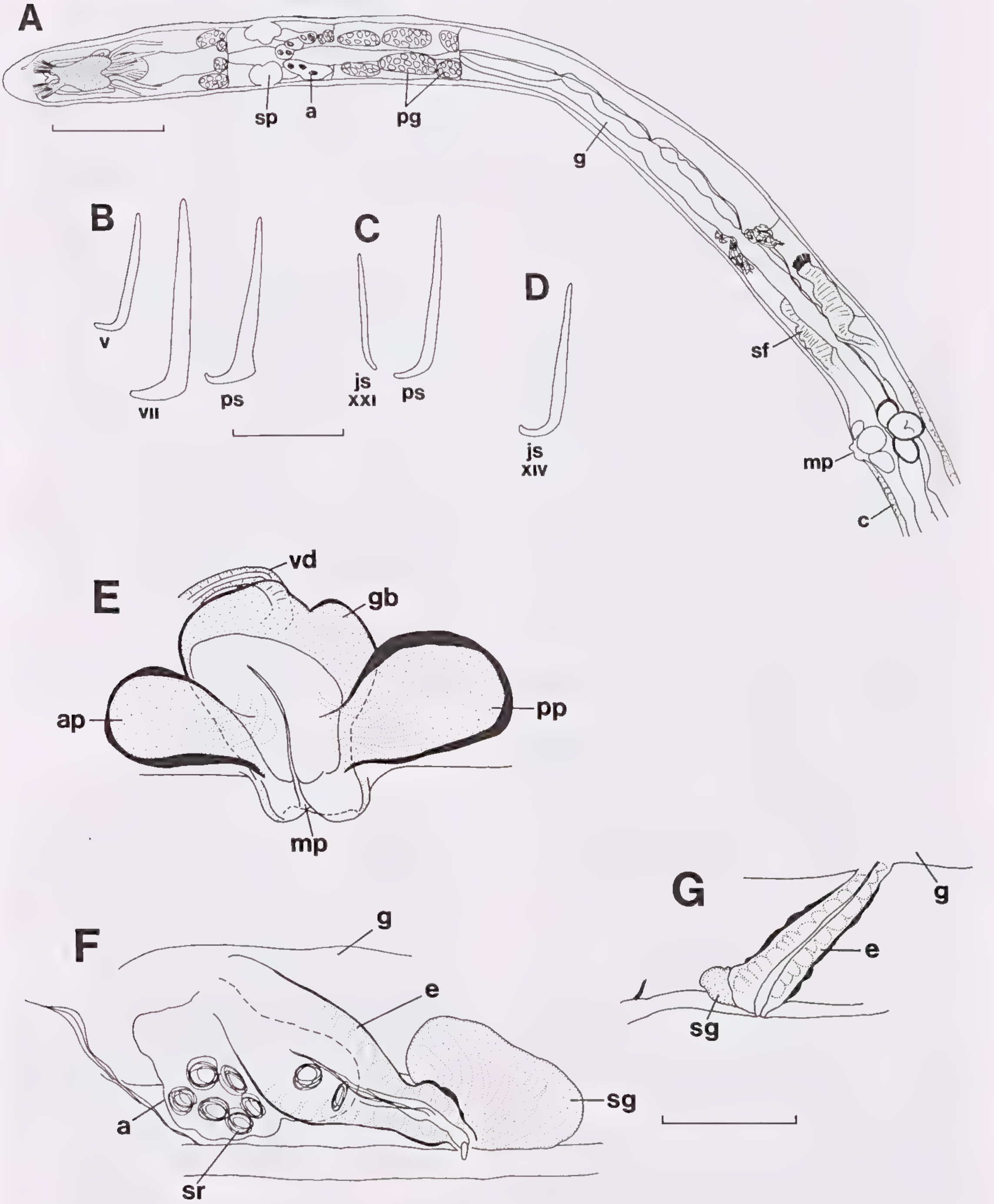

Fig. 1. *Randidrilus darwinensis* sp. nov. **A**, whole mount of holotype, dorsal to dorso-lateral view of anterior of worm, to segment XIII, scale bar equals 200 mm; **B**, **C** and **D**, setae from various segments of a single specimen, **B**, ventral setae; **C**, lateral setae; **D**, juvenile-type ventral seta; **E**, penial apparatus of specimen from Station 52, lateral view; **F**, spermatheca of specimen from Station 52; **G**, spermatheca of a sexually immature specimen from Station 37. **B** through **G** drawn to the same scale, scale bar equals 40 mm.

throughout, extending to XIV. Penial apparatus (Fig. 1E) with median glandular bulb and large subequal anterior and posterior penial glands originating ventrally from central glandular mass; all covered with thin muscle layer; overall length 90-136 mm (n=12, $\bar{x}$=120, s=16). Invagination at male pore simple, of medium size, with vas deferens extending through central glandular mass and opening into invagination along one side. Sperm sac extending as far posteriad as XVIII, egg sac to XIX or XX, rarely more than three segments further back than sperm sac. Spermathecal ectal duct somewhat spindle-shaped tapering to each end, about 62-83 mm long (n=4, $\bar{x}$=73, s=7) with maximum diameter about 30-33 mm (n=3, $\bar{x}$=31, s=2); with very large gland at ectal pore (Figs 1A and 1F). Ampulla saccate, developing at junction of ectal duct and gut, maximum diameter about 30-33 mm (n=3, $\bar{x}$=31, s=2), length about 62-83 mm (n=4, $\bar{x}$=73, s=9), however, outline irregular and variable, with sperm rings embedded in ampullar walls sometimes producing small lobules; spermatheca without ampulla (Fig. 1G) until male system is well-developed and eggs are maturing in egg sac.

Distribution and habitat. Darwin Harbour, Cox Peninsula and adjacent beaches. Known from lower to midintertidal coarse sand, shell substrates, in relatively protected subhabitats among boulders and large rocks. Occasionally found in higher intertidal habitats where water pooled or sediments otherwise remain wet and occasionally found in slightly silty sediments of mid or lower intertidal. Found at salinities as high as 57‰.

Remarks. This was decidedly the most numerous and common of the few lower intertidal enchytraeid species found in this survey of habitats of Darwin Harbour. The species displays characteristics that are held in common with both previously described species of *Randidrilus*, *R. codensis* and *R. quadrithecatus* Coates and Erséus, 1985, and with species of *Grania*. Without making cladistic analyses that formally employ outgroup comparisons as well as simultaneously optimizing the distribution of many character states among species of these two genera, it is clear that a decision to place this new species in either of these genera is coloured by personal biases. The bases of our decision are the unique apomorphic form of the penial bulb, with large, separate, accessory anterior and posterior glands, seen in the new species and other nominal species of *Randidrilus*, as well as the presence of a large gland at the ectal pore of the spermatheca. The penial form described for *Randidrilus* is not recognized in any of the 36 described species of *Grania*, however, a large variation in the penial apparatus is recognized among the nominal species of *Grania*. *Grania stilifera* Erséus, 1990, described from the vicinity of Hong Kong, even has a small, separate glandular lobe extending posteriorly from the epidermal invagination of the male pore but has other characteristics still recognized as unique to *Grania*, i.e., a penial stylet. Only three species of *Grania* have single, rather small glands at the spermathecal ectal pore.

Unlike the other species of *Randidrilus*, the new species has setae and a setal distribution as typical for *Grania*, robust setae with enlarged ental bases lacking from at least segments I through III. It also has well-defined sperm rings which were not noted in other species of *Randidrilus*, but these are also seen in marine species of *Marionina* and are not unique to *Grania*.

Etymology. This species is named for the general area in which it was first discovered, near Darwin, Northern Territory.

Grania Southern, 1913

Grania Southern, 1913: 8-12. - Lasserre 1966: 299, 312-314; - Kennedy 1966:399-407; - Lasserre 1967: 279-280; - Erséus and Lasserre 1976: 121-122; -Coates and Erséus 1985: 110.

Michaelsena Ude 1896 (part). - Pierantoni 1903: 409-410; - Eisen 1904: 73; -Michaelsen 1907: 130-131. - Stephenson 1930: 978; - Knöllner 1935: 449.

Hemigrania Lasserre, 1971: 454.

Marionina Michaelsen 1889 (part). - Nielsen and Christensen 1959: 109-110.

Enchytraeus Henle 1837 (part). - Michaelsen 1888: 66-68; - Pierantoni 1901: 201-202; - Nielsen and Christensen 1959: 89, 91.

Type species. *Grania maricola* Southern, 1913.

Remarks. The most complete recent diagnosis of this diverse genus is given by Coates and Erséus (1985). As more species are described, and given the discovery of a species of *Randidrilus* with "*Grania*-like" characteristics, it is clear that a close and thorough examination of the systematic relationships among the species is necessary. The Australian fauna is known to be morphologically diverse and appears to be largely endemic. In addition, most of the species are recently and relatively completely described. As such, it could serve as a representative group for an initial phylogenetic study of the taxon. For the present, the occurrence of two accessory penial glands and large spermathecal ectal glands distinguish species of *Randidrilus* from those of *Grania*.

Prior to the discovery of *Randidrilus* in Australia, specimens of *Grania* could be readily distinguished from other marine oligochaetes, alive, under a dissecting microscope, by the broad, single setae occurring only from segments somewhat posterior to the mouth and by the stiff nematode-like movements of the worms. Unfortunately, the two lower intertidal enchytraeid genera, as found in the Darwin area, are similar in these attributes. Species of *Grania* and *Randidrilus* are most readily separated by the large gland at the ectal spermathecal pore of *Randidrilus darwinensis*. The behavioural and setal characteristics mentioned, as well as general attributes of enchytraeids, spermathecae in V and male pore in XII, easily allow distinction of species of these genera from other enchytraeids and from long, slender tubificid oligochaetes.

Grania eurystila sp. nov.

(Fig. 2)

Type material. HOLOTYPE - NTM Wo.0081, CE-40, Cox Peninsula, Woods Inlet, approximate location 12° 27.5'S, 130° 45.8'E, outer part of Inlet, intertidal rock pool created by a large cement ring buried in sand, near tidal creek, 16 July 1993, collector C. Erséus. PARATYPES - CE-39, 4 specimens (2 specimens at NTM Wo.0082 and Wo.0083; and two specimens at ROMIZ I2459), outer part of Woods Inlet, approximate location as above, large tidal creek paralleling beach, behind dune; sand, gravel and shell substrate, with some green algae on surface of sediments, 16 July 1993, collector C. Erséus.

Other material. Station CE-10, ROMIZ I2469, 2 specimens; station CE-34, ROMIZ I2461, 1 specimen.

Description. Length 5.8-6.8 mm (n=5, $\bar{x}$=6.4, s=0.5), diameter at V, 71-100 mm (n=6, $\bar{x}$=87, s=12), 73-112 mm at clitellum (n=7, $\bar{x}$=95, s=15) (Fig. 2A), 55, 56, 60 segments. Ventral setae from XV-XVII (Figs 2A-B), lateral setae lacking; setal length midventrally 39-60 mm (n=35, $\bar{x}$=52, s=5), shortest in most anterior setate segments, to 48-60 mm (n=27, $\bar{x}$=55, s=3) in posterior segments. Spermathecal pores lateral, posterior to 4/5. Clitellum extending over about $^1/_2$ XII to $^1/_2$ XIII, granular gland cells not well-developed in available specimens. Male pores ventral at about mid XII; female pores posterior to 12/13, in line of male pores. No midventral glands or epidermal papillae observed. Pharyngeal glands with small dorsal, intraseptal, lobes at 4/5 and 5/6, with ventral lobes extending through V and VI (Fig. 2A). Nephridia not seen in preserved material. Dorsal blood vessel origin about XXIX. Sperm funnel collar equal funnel width; funnel length as many as 15 times width, very long, extending posteriad to XVII-XIX (Fig. 2A) in sperm sac; ectally very granular, then with more obvious globules (?secretions), then granular just before sperm-bearing collar. Vas deferens about 5-8 mm wide (n=7, $\bar{x}$ =6.8, s=0.9) but somewhat variable in diameter over its length. Stylet (Fig. 2C) 158-214 mm long (n=11, $\bar{x}$=181, s=17), diameter relatively consistent throughout length, 4.0-4.8 mm (n=11, $\bar{x}$=4.3, s=0.2), with thick walls each about equal one-third diameter of stylet, extending to an elongate, narrow invagination of the male pore. One specimen without stylets, with poorly developed sperm sac, and sperm funnels without sperm on the collars. Penial apparatus without glandular bulb or with very small gland near male pore (Fig. 2C), primary structure a large, thin-walled (?epidermal) sac surrounding the broad stylet from its ental origin as well as invagination of male pore (Fig. 2C). Female duct thin-walled, without distinct funnel, around 30 mm long. Sperm sac extending as far posteriad as XXXIII, egg sac to XXXIV. Spermathecal ectal duct 67-89 mm long (n=6, $\bar{x}$=78, s=7) (Fig. 2D), maximum diameter about 18-23 mm (n=12, $\bar{x}$=21, s=2). Ampulla (Fig. 2D) sub-rectangular in outline, thick-walled, lying alongside gut and surrounding ectal duct for about two-thirds length of duct, with lumen in ampullar tissue around duct. Ectal duct extending almost through entire length of ampulla. Ampulla with few embedded sperm rings in ental two-thirds of ampullar tissue (Fig. 2D), maximum diameter of ampulla 36-47 mm (n=11, $\bar{x}$=42, s=4), length 65-82 mm (n=11, $\bar{x}$ =72, s=5).

Distribution and habitat. Found only at two locations in the inner part of Darwin Harbour.

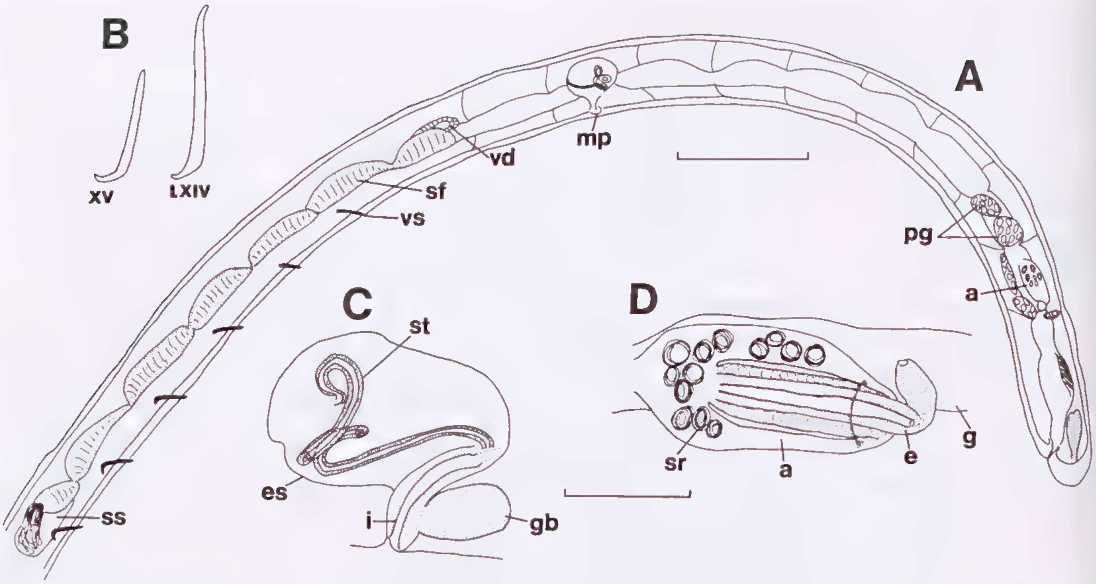

Fig. 2. *Grania eurystila* sp. nov. **A**, whole mount of holotype, lateral view to segment XX, scale bar equals 200 mm; **B**, **C** and **D**, drawn from a specimen from Station CE-10; **B**, setae; **C**, lateral view of penial apparatus; **D**, lateral view of spermatheca. **B** through **D** drawn to the same scale, scale bar equals 40 mm.

In lower intertidal habitats and/or in habitats where water was standing or flowing throughout the tidal cycle; relatively coarse substrates sometimes among boulders.

Remarks. The setal distribution of the new species, with ventral setae only from postclitellar segments, is like *Grania monospermatheca* Erséus and Lasserre, 1976, and *Grania reducta* Coates and Erséus, 1985, known from eastern North America, but unlike any other species described from Australia. Three other species of *Grania*, *G. ovitheca* Erséus, 1977, *G. longiducta* Erséus and Lasserre, 1976, and *G. postclitellochaeta* (Knöllner, 1935), have only ventral setae but these frequently begin in the posterior-most clitellar segment; of these, only *G. longiducta* is known to have stylets (Coates 1984). *Grania monospermatheca* is particularly distinctive in that it has a single, dorsally opening spermatheca, but like the new species it has a relatively large stylet and a highly modified penial apparatus which includes a large sac around the stylet (Coates and Erséus 1985). *Grania reducta* has a simple penial apparatus with neither a stylet nor an enlarged epidermal sac. The form of the stylet of the new species is distinctive, not tapering noticeably from origin to ectal end, with a notably wide diameter, and with very thick walls. (Most observations support the hypothesis that these stylets are tubular.) The spermathecal form of the new species is unlike that described for any other species of *Grania*, with extensive intrusion of the ectal duct through the tissue of the spermathecal ampulla.

Etymology. This species is named for its distinctive, broad, strap-like penial stylet, from the latin *eury*, broad, combined with *stilus*, a style or stake.

Grania integra sp. nov.
(Fig. 3)

Type material. HOLOTYPE - NTM Wo.0079, CE-22, Cox Peninsula, West Point, approximate location 12° 26.2'S, 130° 46.0'E, lower intertidal crevice with sand, gravel and pebbles under rocks, 11 July 1993, collector C. Erséus. PARATYPE - NTM Wo.0080, one specimen, data as for holotype.

Other material. Station 33, ROMIZ I2464, 1 specimen, station 37, ROMIZ I2465, 1 specimen, station 63, ROMIZ I2466, 1 specimen, station CE-16, ROMIZ I2463, 1 specimen.

Description. Length 6.0-10.8 mm (n=6, $\bar{x}$=9.0, s=1.6), diameter at V, 108-140 mm (n=6, $\bar{x}$=0.120, s=0.013), at clitellum about 126 mm (Fig. 3A), 60-77 segments (n=5, $\bar{x}$=66.2). Ventral setae from IV or V (Fig. 3B), more posterior setae curved at ectal tip and sharply pointed (Fig. 3B), lateral setae lacking; anterior setal length 44-61 mm (n=14, $\bar{x}$=55, s=4.8), midventral setae with similar range and mean length,

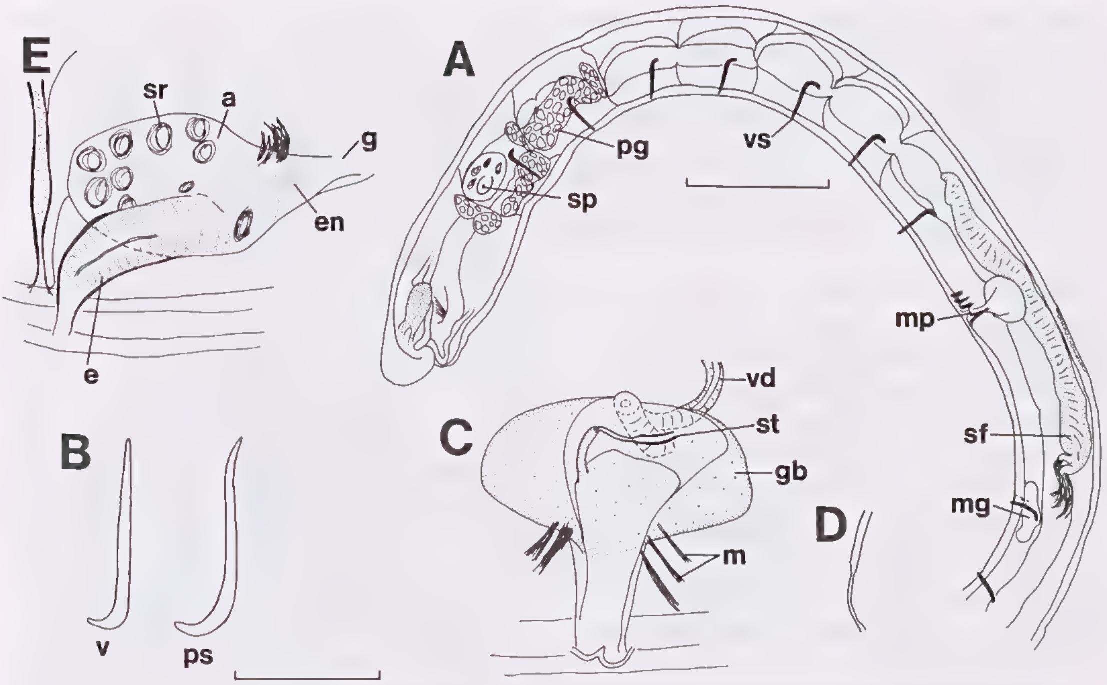

Fig. 3. *Grania integra* sp. nov. **A**, whole mount of specimen from Station 63, lateral view of anterior segments, to **XV**, scale bar equals 200 mm; **B**, setae from the same specimen; **C**, penial apparatus of specimen from Station CE-16, lateral view; **D**, stylet of specimen from Station CE-22; **E**. spermatheca of specimen from Station 33, ventrolateral view. **B** through **E** are drawn to the same scale, scale bar equals 40 mm.

posterior setae 56-69 mm (n=26, $\bar{x}$=65, s=3.3). Shed setae present in coelom. Spermathecal pores paired laterally, near 4/5. Clitellum extending over XII to mid XIII, glands strongly developed only from behind male pores to anterior of XIII. Male pores ventrolateral near mid XII; female pores just lateral to line of male pores, posterior to 12/13. Medium-sized midventral gland and associated epidermal papilla in XIV. Anus directed somewhat ventrad. Pharyngeal glands with dorsal, intraseptal lobes at 4/5 through 6/7; small ventral lobes in IV, extending through V and VI (Fig. 3A). Nephridia not seen in fixed material. Dorsal blood vessel origin from XXV to XXXIII. Sperm funnel with collar about equal to funnel width, with nonglandular region separating it from rest of funnel, about equal in length to height of collar; funnel (Fig. 3A) extending posteriad in sperm sac as far as XVIII, usually about XV, length several (5-10) times width. Vas deferens diameter about 8-10 mm (n=6, $\bar{x}$=8.4, s=0.7), more or less regular throughout length. Penial apparatus with large gland and relatively small, simple, saccate invagination of male pore (Fig. 3C). Stylet (Figs 3C-D) about 31-41 mm long (n=5, $\bar{x}$=35, s=4), diameter at origin 2-2.5 mm (n=6, $\bar{x}$=2.2, s=0.2), narrowing abruptly at about one-half of its length to just less than 1 mm (n=6, $\bar{x}$=1.0, s<0.1), may flare slightly at ectal end; ectal end protruding into thin-walled lumen of saccate invagination of male pore. Sperm sac extending as far posteriad as XXI, egg sac to XXVII. Spermathecal ectal duct with thin exterior muscle layer, length 56-59 mm (n=4, $\bar{x}$=57, s=2), maximum diameter about 17-24 mm (n=5, $\bar{x}$=19, s=3) (Fig. 3E). Ectal duct uniting with ampulla near ental end of ampulla. Ampulla large and saccate, extending mediodorsal to duct (Fig. 3E), maximum diameter 36-47 mm (n=9, $\bar{x}$=42, s=4), length 59-82 mm (n=9, $\bar{x}$=69, s=7); ental duct broadly connected to side of gut in posterior one-third of V. Numerous sperm rings embedded in tissue of ampullar wall.

Etymology. Named for the completeness of the penial apparatus, including a stylet, from the latin *integer*, complete.

Remarks. The combination of a saclike spermathecal ampulla with a penial stylet and absence of lateral setae is found in a few other species of *Grania*, as noted above in remarks on *G. eurystila*, but the new species differs from each of these in a number of structural characters. *Grania longiducta* Erséus and Lasserre, 1976, shares the three character states mentioned above but has the ventral setae beginning in intra- or postclitellar segments, a long spermathecal ectal duct and small, saccate ampulla, and a longer, more than 50 mm, penial stylet. In addition, it has a comparatively short sperm funnel that is not known to extend through a number of posterior segments as seen in the new species.

In fact, the species that seems most similar to *G. integra*, in a number of characters, is an Australian species which lacks stylets, *G. vacivasa* Coates and Stacey, 1993, described from Rottnest Island. This species is about twice as large as *G. integra*, has ventral setae beginning in segment IV or V, a similar spermathecal form, although a conical protrusion of the ectal duct into the ampulla was noted, a very long, posteriorly extended sperm funnel, and a penial apparatus with a compact gland and small epidermal sac extending from the male pore; however, a stylet is lacking.

Grania vacivasa was originally described from three specimens so that its intraspecific variation has not been fully explored. So far, extensive variation in the presence of a stylet has not been noted among fully mature specimens of a single species, however, in these collections, a specimen without stylets that clearly belongs to *G. eurystila* was found. No species or subspecies pairs of *Grania* that are identical other than in the presence of a penial stylet have been recorded (also see Discussion, below).

Distribution and habitat. Found at a number of locations around Darwin Harbour. In coarse sand and shell sediments from mid to lower intertidal, frequently with *Randidrilus darwinensis*.

Grania sp.
(Fig. 4)

Material examined. Station 13, 1 specimen, ROMIZ I2462.

Description. The following description is based on a single, partially mature specimen without eggs. Length 7.1 mm, diameter at V, 125 mm, 140 mm at clitellum (Fig. 4A), 52 segments. Ventral setae from V (Fig. 4A), length about 58-62 mm (n=10) (Fig. 4B), lateral setae (Fig. 4B) from XV, length about 46-59 mm (n=10), laterals thin from about XVI through XX. Spermathecal pores paired, midlateral, somewhat posterior to 4/5 (at about one-sixth length of the segment). Clitellum extending over XII to $^{1}/_{2}$ XIII, no special distribution or pattern of gland cells noted, not well-developed in this specimen. Male pores ventral near mid XII; female pores not seen. No midventral glands or epidermal papillae noted. Pharyngeal glands (Fig. 4A) with dorsal, intraseptal, lobes at 4/5 and 5/6, with ventral lobes just anterior to 4/5 and extending through V and VI. Nephridia not seen in fixed material. Dorsal blood vessel origin in anterior of XIX. Sperm funnel collar not clearly seen; sperm funnel length several times width, extending posterior to clitellum (Fig. 4A). Vas deferens extending to XIV, diameter about 5-6 mm at junction with penial sac (Fig. 4C). Penial apparatus without stylet. Simple globular penial gland (Fig. 4C), about 67 mm (65, 69) diameter with thin muscular layer surrounding it; glandular bulb surrounding simple, elongate, epidermal invagination. Whole penial apparatus with longitudinal muscles surrounding base, giving a somewhat stalked, or mushroom-like appearance. Sperm sac extending to posterior of XVI, egg sac not developed. Spermathecal ectal duct relatively short and stout, with muscular outer layer, length about 48 mm, maximum diameter about 28 mm, tapering slightly entally and protruding into base of ampulla (Fig. 4D). Muscle strands from outside of duct extend onto ampulla. Ampulla ovoid, attached entally to side of gut by short narrow duct (Fig. 4D), length of ampulla, 39, 43 mm, about equal diameter, maximum diameter of ampulla less than twice the diameter of ectal duct, 40, 45 mm; with a few embedded sperm rings, sperm otherwise loosely distributed in canals of ectal and ental ducts and in restricted cavity of ampulla.

Remarks. This single specimen shows similarities to *Grania principissae* (Michaelsen, 1907), known only from Western Australia (Coates 1990), in penial bulb form and setal distribution. The very simple form of penial bulb seen in these taxa is only clearly documented for this specimen, *G. principissae*, *G. conjuncta* Coates and Stacey, 1993, both described from Australia, *Grania hongkongensis* Erséus, 1990, from the south coast of China, and *G. reducta* Coates and Erséus, 1985, known from the western Atlantic, and it has been reported in a couple of undescribed taxa from Sweden and France (Coates 1984). The junction of the ectal duct of the spermatheca and the spermathecal ampulla are quite different among these taxa, with the ental end of the duct protruding into the ampulla in the recent material. The new material differs from the few known

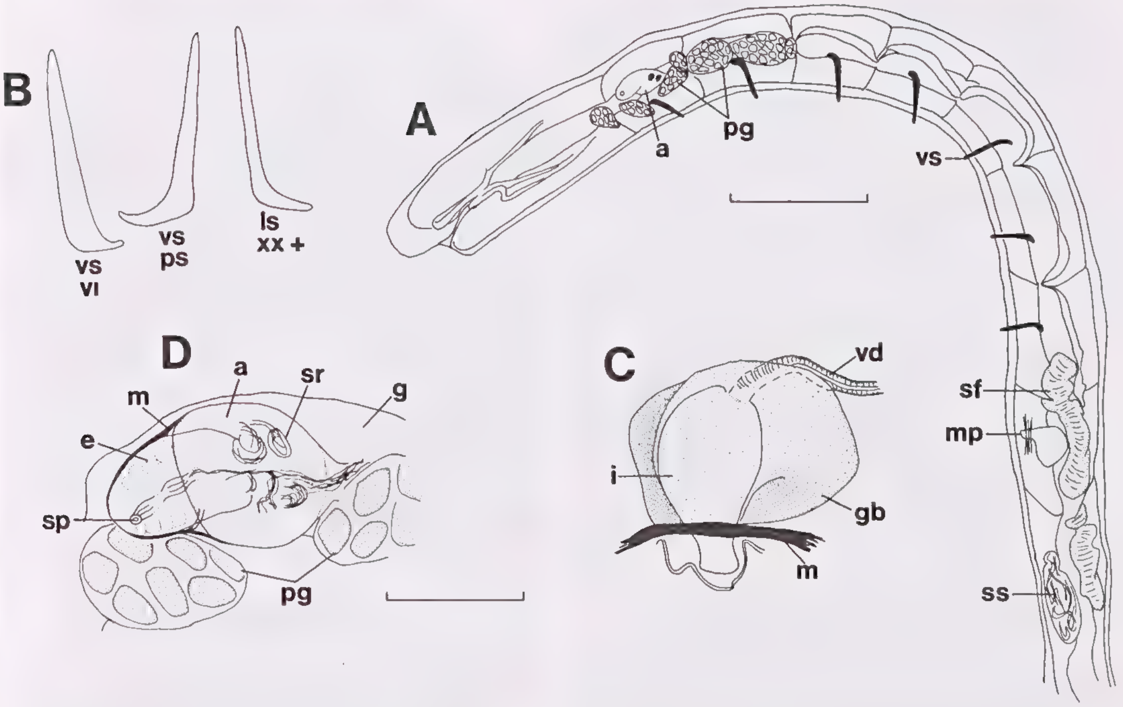

Fig. 4. *Grania* sp. **A.** whole mount, lateral view of anterior segments, to XIII, scale bar equals 200 mm; **B**, ventral and lateral setae of various segments; **C**, lateral view of penial apparatus; **D**, lateral view of spermatheca. **B** through **D** drawn to same scale, scale bar equals 40 mm.

specimens of *G. principissae* in having almost twice as many segments and robust, broad setae with pronounced ental enlargements. *Grania conjuncta* does not have lateral setae and a dorsal union of the spermathecal ampullae with the gut is so broad that the ampullae appear joined. *Grania reducta* also lacks lateral setae and has a somewhat saccate spermathecal ampulla. *Grania hongkongensis* has a small, relatively short sperm funnel and ventral setae beginning much more posteriad but has a similar spermathecal form to this unnamed specimen. The form of the spermatheca of the new species is most like that seen in *Grania crassiducta* Coates, 1990 (Coates and Stacey 1993: fig. 9E), but that species has a penial stylet and a large, saccate, epidermal invagination at the male pore.

As can be seen from the description, although this was a relatively mature, well-preserved specimen, there was some mechanical distortion in the clitellar region, and it was not possible to see clearly all the internal structures, in particular, the sperm funnel.

Distribution and habitat. Found only at one site on the Cox Peninsula, at about mid-intertidal elevation on steeply sloping beach south of Mandorah Inn; near low intertidal rocky reef at Oak Point, in an area of seepage where beach sediments were blackened, probably due to deposition of iron.

DISCUSSION

The diversity of species of *Grania* in the Darwin area was not as high as found at earlier workshops in Western Australia but, as in those collections, the species reported here are all only known locally. This suggests that the genus has undergone substantial diversification along the entire coast of Australia. Nonetheless, it is likely that the distribution of individual species will be found to be broader than what is now known, as reported for *Grania ersei* Coates, 1990, and *G. crassiducta* along the coast of Western Australia (Coates 1990; Coates and Stacey 1993).

Even though the species diversity of the lower intertidal enchytraeids in the area of Darwin Harbour was not found to be high, a new generic record has been made for the continent with the discovery of *Randidrilus darwinensis*. This discovery and the characteristics of the new species have also raised questions about the relationships among species of *Grania* and *Randidrilus* as they are now found to share setal form and distribution characteristics that are otherwise unique among the enchytraeids.

The discovery of *G. integra* in the area of Darwin, a species with a penial stylet, has led to questions about the variability of the presence of a stylet in sexually mature specimens of the genus. This species is most like *G. vacivasa*, described from around Rottnest Island, Western Australia, but which does not have stylets. In fact this species was so-named because the penial apparatus includes most of the structures seen in conjunction with a stylet but, instead, the vas deferens was empty at its ectal end. A comparable situation in structure of the penial apparatus was noted by Erséus (1990) for *G. inermis*. As an indication of possible loss or absence of the stylet at some stage of maturation, perhaps postcopulatory, a single specimen of the new species *G. eurystila* was found that did not have a penial stylet. Both these findings indicate that studies of variation in the development, function, and loss of stylets might provide useful information to taxonomic studies of *Grania*.

As noted earlier, variation in the presence of a stylet has not been recorded previously, even in collections of easily distinguished taxa for which large numbers of specimens are available, such as *G. ersei* (Coates 1990; Coates and Stacey 1993).

This study expands the list of intertidal species of *Grania* reported from Australia from 12 to 14, with an additional unnamed, poorly sampled species also represented in the Darwin collection. It also adds a new genus to the enchytraeid fauna of Australia, *Randidrilus*, and provides the first records of this genus outside of the western Atlantic Ocean.

The coastline of the Northern Territory is very long and varied so that this can be regarded as, at best, a beginning of the study of lower shore marine enchytraeids of the region. The diversity of species of *Grania* is high in other areas along the extensive Australian coastline (Coates 1984). Given the variety of habitats that occur along the coast of Northern Territory, it would be surprising if its marine enchytraeid fauna were not comparably diverse.

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ENCHYTRAEIDS (OLIGOCHAETA: ANNELIDA) OF THE MID AND UPPER INTERTIDAL OF DARWIN HARBOUR, NORTHERN TERRITORY, AUSTRALIA.

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ABSTRACT

Enchytraeids were collected from the mid and upper intertidal zones in Darwin Harbour during the Sixth International Marine Biological Workshop in July 1993. A wide range of habitats was sampled at 15 localities, including mangroves. Highest density and diversity were recorded from moist, well-drained substrates, especially strandline debris at high water mark, the banks of creeks and mounds of the mangrove mudlobster *Thalassina anomala*. Eight species are recorded including two, *Marionina coatesae* and *M. nevisensis*, previously known from Western Australia. *Stephensoniella marina* and *S. trevori* are new records for Australia. Four new species are described: *Marionina gabiae, M. mangle* and *M. tumulicola*, all from mangrove habitats, and *M. mandorae* from tidal debris at high water mark.

KEYWORDS: *Marionina, Stephensoniella*, taxonomy, ecology, marine, beaches, mangroves.

INTRODUCTION

This paper records species of Enchytraeidae collected from the middle and upper intertidal zones during the Sixth International Marine Biological Workshop on the Marine Flora and Fauna of Darwin Harbour in July 1993. Habitats sampled included tidal debris, mangroves and tidal creeks as well as rocky shores, sandy beaches and mud flats. The enchytraeid fauna of the lower intertidal zone was similar to that of the sublittoral, comprising members of the genera *Randidrilus* and *Grania* only, and is the subject of a separate paper (Coates and Stacey 1996).

There are no records of enchytraeids from marine habitats in northern Australia, or indeed from freshwater or terrestrial biotopes in the region. The only Australian records of marine species are from the Great Barrier Reef where *Grania macrochaeta trichaeta* was described from just below mean low water mark (Jamieson 1977) and the south-west where Michaelsen (1907) reported *Grania principissae* (as *Michaelsena*) and the widespread *Enchytraeus albidus* Henle, and where two recent intertidal surveys in Albany (Coates 1990) and Rottnest Island (Coates and Stacey 1993) produced records of five species of *Marionina*, eleven species of *Grania* and one species of *Lumbricillus*.

The aims of our survey were to identify the species present in the region and to define their ecological limits and preferences. Ecological distribution was determined by sampling a wide range of ecological conditions, including some habitats which were unlikely to support enchytraeids because they were rather dry or deficient in oxygen.

In: Hanley, R.H., Caswell, G., Megirian, D. and Larson, H.K. (eds) *Proceedings of the Sixth International Marine Biological Workshop. The marine flora and fauna of Darwin Harbour, Northern Territory, Australia.* Museums and Art Galleries of the Northern Territory and the Australian Marine Sciences Association: Darwin, Australia, 1997: 81–97.

MATERIALS AND METHODS

Samples were taken from both east and west coasts of Darwin Harbour (approximately 12°50'S, 131°00'E) within a range of 15 km of Darwin City. The spring tidal range in this region reaches eight metres (predicted range 6.74 m during the sampling period) and the tidal zone is therefore broad, reaching 500 m in places. The lower shoreline consists principally of coarse, sandy beaches or mud flats with a few scattered outcrops of rock. The beaches are bordered in some places by dunes, rock or scrub but mangroves dominate the zone above mean tide level in all the more sheltered areas. Mangroves are particularly well developed in the muddy inlets where four or five distinct vegetation zones may be represented and the mud fauna is abundant and diverse. In the more exposed, sandy areas, the mangroves are less extensive, the vegetation not so dense and faunal diversity is lower.

Samples were taken from 15 localities, representing the main community types, between 6-21 July 1993, i.e. in the dry season. At each locality, a range of habitats was sampled in an effort to determine the ecological distribution of the species. Salinities were estimated using a hand-held refractomer, calibrated for salinity. Enchytraeids were mainly to be found in moist but well drained substrates near the upper tidal limit. Sampling effort was therefore concentrated in this zone.

Collecting and extraction methods varied according to the nature of the substrate. Specimens were extracted from sand by flotation and screening on a 360 µm or 500 µm sieve and from mud by washing through the same sieves. The residues were sorted microscopically while the worms were alive. Where there were large amounts of organic material in the residue, wet funnel extraction was used to recover the enchytraeids. The method employs heat and light from light bulbs to expel worms (and other mobile invertebrates) from samples in water-filled funnels (O'Connor 1955; Healy and Rota 1992). This method was also used, without pre-screening, for some tidal debris samples and for peaty substrates.

The majority of mature specimens were fixed in Kahle's fluid (glacial acetic acid 2%, formalin 11%, 95% ethanol 20%, water 67%), stained in borax carmine or paracarmine and whole mounted in Canada Balsam, but some were kept alive on seawater agar plates (Healy and Rota 1992) for later examination and photography. Not all of these survived, those from wet habitats being the least hardy. Observations were made using differential interference contrast light microscopy and colour photomicrography was used to record features of live specimens. Figures are camera lucida drawings, simplified where necessary. Unless otherwise stated, fixed specimens were used for measurements of internal organs and drawings. Separate drawings of structures in live individuals are given only when these were not seen in fixed material or when fixation altered the form of an organ.

Holotypes and paratypes are deposited at the Museums and Art Galleries of the Northern Territory, Darwin (NTM Wo). Other material, including some paratypes, is deposited at Invertebrate Zoology, Royal Ontario Musem, Toronto, Canada (ROMIZ) or retained in the collection of B. Healy (BH.DW).

Sampling stations. Only stations at which the species recorded in this paper were found are listed and described. Other localities sampled, where no identifiable enchytraeids were found, were Lee Point sandy beach, Buffalo Creek mangrove, Rapid Creek mangrove, Darwin Port mudflat, West Point sand and rocks, Channel Island rocky shore and Mandorah sandy beach (clean section without stones) south of the hotel. Habitats where no enchytraeids were found, or where enchytraeids were unidentifiable, are discussed under "Occurrence of enchytraeids". Note that some localities were visited twice. One station was sampled by K. Coates (KAC), all others were sampled by B. Healy.

Abbreviations. Abbreviations used in the figures. **a**, aperture; **am**, spermathecal ampulla; **b**, brain; **c**, collar; **d**, diverticulum; **e**, egg; **ed**, spermathecal ectal duct; **eg**, ectal glands; **g**, gland; **i**, intestine; **nc**, nerve cord; **o**, ovary; **p**, pharyngeal gland; **pb**, penial bulb; **s**, spermatheca; **sf**, sperm funnel; **sfg**, sperm funnel, glandular portion; **sfn**, sperm funnel, non-glandular portion; **sr**, sperm ring; **sv**, seminal vesicle; **t**, testis; **v**, vas deferens.

OCCURRENCE OF ENCHYTRAEIDS.

Samples were taken from 101 stations at 15 localities, but mature, identifiable enchytraeids were found at only 28 stations/habitats at nine localities. Enchytraeids were absent or very rare in wet mud e.g. creek bottoms, the surface mud

Table 1. Sampling station details.

Station #	Locality	Description
3	Mandorah, sand beach between hotel and boat pier. 6 July, 1993	Moist tidal debris (sargassum, leaves, sticks etc.) at high water mark. (*Marionina mandorae, M. coatesae*)
19	Sadgroves Creek, in mangrove. 7 July, 1993	Soft mud on sloping bank of main creek. (*Marionina mangle*)
20	Sadgroves Creek, in mangrove. 7 July, 1993	Mudlobster mound in lower *Bruguiera* zone. Dry at the surface, moist and fibrous within with numerous burrows of polychaetes and small crabs. (*Stephensoniella trevori, Marionina mandorae, M. tumulicola*)
30	Mandorah (same as Stn. 3). 8 July, 1993	Moist sand under moist tidal debris at mean high water of spring tides. *Pontodrilus* present. (*Stephensoniella marina, S. trevori, Marionina mandorae*)
31	Mandorah (same as Stn. 3). 8 July, 1993	Moist sand under dry debris at a higher level. No *Pontodrilus*. (*Stephensoniella trevori, Marionina mandorae*)
41	Imaluk, bank of creek just below mangrove. 10 July, 1993	Muddy sand among pneumatophores of *Avicennia*, compact, with a few crab burrows. (*Stephensoniella marina*)
42	Imaluk, in mangrove, inland from Stn. 41. 10 July, 1993	Eroding bank of creek. Hard, sculptured lumps of peaty mud, brown on surface, black inside. Salinity of creek water 25‰. (*Marionina gabiae, M. mandorae*)
46	Sadgroves Creek, in mangrove. 11 July, 1993	Sloping bank of main creek, just above low water level. Surface 1-2 cm of soft mud with some fibre. (*Marinina mangle, M. tumulicola*)
47	Sadgroves Creek, in mangrove. 11 July, 1993	Vertical bank of main creek, riddled with crab burrows. Firm, fibrous mud, brownish at surface, dark grey below. (*Marionina mangle*)
50	Sadgroves Creek, in mangrove. 11 July, 1993	Old mudlobster mound in upper *Avicennia* zone. Many small crab burrows and surface pitmarks. Rich in fibre. (*Marionina mangle*)
53	Sadgroves Creek, in mangrove. 11 July, 1993	Drier mudlobster mound in lower *Bruguiera* zone. Sample from outer crust and lining of main burrow. (*Marionina mangle, M. tumulicola*)
57	Ludmilla Creek, upper mangrove. 12 July, 1993	Wet, silty gravel at edge of small creek. Salinity of creek water 40‰. (*Stephensoniella trevori, Marionina gabiae*)
59	Ludmilla Creek, above main mangrove. 12 July, 1993	Moist leaf litter, not wet. (*Stephensoniella trevori*)
60	Wood's Inlet, in mangrove. 13 July, 1993	Shelly, gravelly mud at edge of main creek, lumpy and dark with some crab burrows. (*Marionina gabiae*)
61	Wood's Inlet, in mangrove. 13 July, 1993	Dry bed of small stream in *Rhizophora* zone, subject to occasional tidal flooding. Moist, gravelly mud with roots, rich in organic matter. (*Marionina nevisensis*)
62	Mandorah beach	Moist depression at edge of mangrove, reached by spring tides only. Moist, fine-medium sand under dry mangrove leaves. (*Stephensoniella marina, S. trevori*)
63	Mandorah, just S of hotel. 14 July, 1993	Smalll mudlobster mounds in sandy mangrove, (*Ceriops decandra* dominant). Mounds rather dry with hard outer crust and no apparent burrows. (*Stephensoniella marina*)
70	Wood's Inlet, creek leaving mangrove. 14 July, 1993	Eroding bank of main creek. Sand and silt with *Avicennia* roots and fibrous organic matter. (*Marionina nevisensis*)
72	Wood's Inlet, mangrove to north of creek. 14 July, 1993	Sandy mud among mangrove roots. (*Marionina mangle*)
81	Stephen's Creek tributary. 15 July, 1993	Bank of stream in "freshwater mangrove", moist soil with a few crab burrows. (*Marionina tumulicola*)
85	Ludmilla Creek, in mangrove. 16 July, 1993	Bank of main creek. Moist muddy sand with a few crab burrows. (*Marionina gabiae*)
90	Wood's Inlet, landward edge of mangrove. 18 July, 1993	Moist sand under tidal debris (mangrove leaves and sticks) on sandbank with palms. (*Stephensoniella trevori*)
91	Wood's Inlet, near Stn. 70. 18 July	Muddy sand with fibrous organic matter on bank of inlet, among *Avicennia* roots. (*Stephensoniella trevori, Marionina coatesae*).
92	Mandorah, hotel harbour at HW mark. 18 July, 1993	Gravel and stones under fresh sargassum debris. Talitrids and woodlice present. (*Stephensoniella marina*)
94	Mandorah, hotel harbour slipway. 18July, 1993	About mid tide level. Medium sand with stones. (*Stephensoniella marina*)
97	Hudson Creek, in mangrove. 19 July, 1993	Mudlobster mound in *Rhizophora* zone. Silt with fine sand and large proportion of fibre. Many small crab burrows. (*Marionina mangle*)
98	Hudson creek, in mangrove, as Stn. 97. 19 July, 1993	Larger, drier mudlobster mound near stream. (*Marionina tumulicola*)
KAC 50	Mandorah beach, S of hotel. 16 July, 1993	Cobble beach in mid-intertidal zone, coarse sand and gravel under stones with drainage water flowing. (*Stephensoniella trevori*)

of mangroves and the mudflats of Darwin Port, and in algal turf, rock crevices, rock pools and other habitats on rocky shores. In wet habitats, enchytraeids were often replaced by Tubificidae and the two families rarely occurred together. On sandy beaches, a few were taken from shallow pools around mid tide level but none were found in clean sand of the middle and upper shore, even at depths at or near the water table. Enchytraeids were, however, present in the coarse sediments of the lower shore where they were represented by the genera *Randidrilus* and *Grania* (Coates and Stacey 1997). The highest concentrations of enchytraeids occurred in moist but well-drained substrates such as decomposing strandline debris and the sand beneath, the banks of mangrove creeks and the mounds of the mangrove mudlobster, *Thalassina anomala*. Enchytraeids were not recovered from other mangrove habitats, i.e. pneumatophores of *Avicennia* with algal growths, pealing bark on *Bruguiera* "knees", rotting wood and algal mats.

SYSTEMATICS

Genus *Stephensoniella* Cernosvitov, 1934, emended Coates, 1983

Type species. *Enchytraeus marinus* Moore, 1902.

Stephensoniella marina (Moore, 1902)
(Fig. 1A-B)

Enchytraeus marinus Moore, 1902: 80-82, fig. 1.

Stephensoniella marina - Cernosvitov 1934: 233-237; 1935: 8, Plate 1, figs 1-4.

Enchytraeus barkudensis Stephenson, 1915a: 142; 1915b: 45-47.

Stephensoniella barkudensis - Cernosvitov 1934: 242-243.

Stephensoniella barcudensis - Cernosvitov 1937: 291.

Stephensoniella marina - Lasserre and Erséus 1976: 455; - Coates 1983a: 413-415, figs 1-3; - Erséus 1990: 316-317, fig. 25 A-B.

Material examined. Five whole mounts, NTM Wo0116-0120; nine whole mounts, ROMIZ 13256 (6), 13257 (1), 13258 (2); six whole mounts, BH.DW; from Stations 30 (2), 31 (1), 62 (10), 63 (1), 94 (3). Five live specimens examined from Stations 41(1), 62 (3), 92 (1).

Brief description of new material. White or pinkish worms, live length about 15 mm, fixed length 7.0-16.9 mm ($\bar{x}$=11.0, sd=3.0, n=17). Segments 43-65 ($\bar{x}$=51.6, sd=6.34, n=17). Setae 3 laterally and ventrally in front of clitellum, two per bundle behind, (58)74-102 µm, noticeably shorter in II and sometimes in III. Clitellar glands in transverse rows, sometimes absent ventrally between penial bulbs. Septa thickened at 6/7-9/10. Dorsal vessel from XIX or XX, blood red in live individuals. Coelomocytes spindle-shaped 24-30 µm in length. Seminal vesicles reaching from 9/10 into XII. Sperm funnel 160-300 µm long, two to three times longer than wide, length a quarter to a half width of worm. Vas deferens 8-12 µm in diameter. Spermatheca more or less spherical, with a smooth, thick wall and a single, thin-walled, cylindrical diverticulum reaching 210 µm in length. Sperm abundant in diverticulum, small amounts in ampulla. In four specimens from Station 62 in which the ampulla contained no sperm, its outer wall was lobed (Fig. 1A-B). Ectal duct 26-28 µm across, up to 370 µm long, usually bent double.

Remarks. Specimens varied considerably in length and segment number but the proportions of organs remained roughly the same. Size and segment number are generally within the recorded range for the species (Coates 1983a; Erséus 1990) although the maximum length was somewhat greater. The material departs from previous descriptions in a more anterior origin of the dorsal vessel (in most specimens), in the smaller size of the sperm funnel relative to the width of the worm, i.e. less than half instead of nearly equal, and the greater length

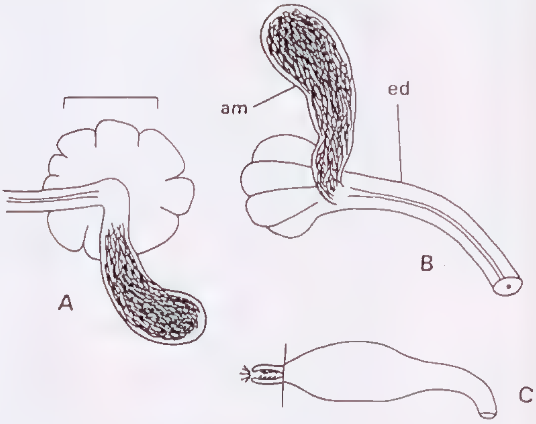

Fig. 1. *Stephensoniella marina*. **A** and **B**, two views of the lobed spermatheca seen in four specimens. *Stephensoniella trevori*. **C**, postclitellar nephridium. Scale bar 50 µm.

of the spermathecal ectal duct. The presence of red blood, seen in live individuals but not apparent in fixed material, has not previously been mentioned. Specimens with a lobed spermathecal ampulla showed no other distinguishing features and the condition may be a transitory developmental stage.

Distribution and habitat. Barkuda Is., India; French Guyana; Florida, U.S.A.; Bermuda; Arabian Gulf, Saudi Arabia; China. New for Australia. In the present survey, in sand under strandline debris and among stones around mid tide level. Frequent at Station 62.

Stephensoniella trevori (Coates, 1980)

(Fig. 1C)

Marionina trevori Coates, 1980: 1311-1313, figs. 17-22; Coates and Ellis 1981: 2137.

Lumbricillus sterreri Lasserre and Erséus, 1976: 453-454 (partim).

Stephensoniella trevori - Coates 1983a: 416-418, fig. 3.

Material examined. Five whole mounts, NTM Wo0111-0115; nine whole mounts, ROMIZ 13253 (7), 13254 (1), 13255 (1); 11 whole mounts, BH.DW; from Stations 30 (9), 31 (3), 57 (1), 59 (1), 62 (7), 90 (1), 91 (1), KAC 50 (2). Six live specimens examined from Stations 20 (1), 30 (1), 62 (3), 90 (1); five live specimens from Bermuda.

Brief description of new material. Length of live specimens about 6 mm, fixed length 4.4-7.7 mm, ($\bar{x}$=5.6, sd=1.07, n=13), diameter 0.20-0.38 mm. Segments 37-52 ($\bar{x}$=43.8, sd=4.7, n=25). Setae 39-65 μm long, two in all lateral bundles, usually present in XII, ventrally three in preclitellar segments, absent in XII, two in postclitellar segments. Clitellum in fully mature specimens with 35-40 rows of small, granular, gland cells, separated dorsally by clear interspaces, more closely packed laterally, absent ventrally between the penial bulbs. Thickened septa from 7/8 to 8/9 or 9/10. Pharyngeal glands broadly united with small ventral lobes. Chloragocytes tall, closely set, packed with oil globules in live specimens. Dorsal vessel originating in XIII or XIV. Coelomocytes small, numerous, oval or spindle-shaped, 9-18 μm in length. Brain with straight posterior and straight or concave anterior borders. In live specimens, postseptale of nephridium (postclitellar region) with stout efferent duct, not demarcated (Fig. 1C). Paired seminal vesicles reaching 10/11 or 9/10. Sperm funnel about 180 μm long, bent into a semicircle in fixed specimens. In live individuals, it is about twice as long as wide and a little over half the diameter of the body, densely granular in its proximal half or two thirds. Vas deferens 8 μm in diameter, about three to four times length of sperm funnel, coiled into a tight mass, opening at a compact bulb, 46-80 μm long. Spermathecal ampulla thick-walled, a little longer than wide, length 64-100 μm, with a thinner-walled, globular diverticulum of about same size, sperm in diverticulum only, usually arranged in a ring in live specimens. Ectal duct without surface glands, 14-16 μm in diameter, length about the same as that of ampulla, opening through a ring of small gland cells (seen clearly in one live specimen).

Remarks. The present material differs in several respects from that described from other localities (Canada, Bermuda, Saudi Arabia) although size and segment number are within the range recorded (Coates 1983a). Setae are somewhat smaller and the coelomocytes are considerably smaller than those described by Coates (1980) which were more than half the length of the setae, while the nephridial efferent duct, when seen in live specimens, was not sharply demarcated as in Coates (1980: fig. 20). Another difference is the narrower and longer vas deferens. Coates (1983a) gives a diameter of 10-14 μm and a length only two to three times as long as the sperm funnel. Characters not previously mentioned are abundant oil globules in the chloragocytes (dissolved out by clearing agents and therefore not visible in mounted material) and the arrangement of the clitellar gland cells.

Distribution and habitat. British Columbia, Canada; Bermuda; Arabian Gulf, Saudi Arabia; Brazil. New for Australia. Upper or mid-intertidal, in sand with organic debris and in finer sediments. In the present survey, in sand under tidal debris, in the banks of creeks and among stones around mid-tide level. Common at Stations 30 and 62.

Genus *Marionina* Michaelsen, 1889

Type species: *Pachydrilus georgianus* Michaelsen, 1888.

Marionina gabiae sp. nov.

(Fig. 2)

Type material. HOLOTYPE - NTM Wo0101, stained whole mounted specimen, Ludmilla

Creek mangrove (Stn 57), collector B. Healy, 12 July 1993. PARATYPES - six whole mounts, NMT Wo0102-0107; seven whole mounts, ROMIZ 13249-13251, 13297-13300; from Stations 42 (8), 57(1), 60 (3), 85 (1).

Type locality. Ludmilla Creek, Station 57. Wet silty gravel on the bank of a small tidal creek in the upper mangrove zone, salinity of creek water 40‰.

Other material. BH.DW, 25 whole mounts from Stations 42 (6), 57 (12), 60 (7). Two live specimens examined.

Description. Length of two live individuals 6.5 mm, diameter 0.18 mm, 0.21-0.25 at the clitellum. Fixed length 2.2-4.2 mm ($\bar{x}$=3.12, sd=0.58, n=17), diameter at VII 0.16-0.22 mm, 0.20-0.26 mm at the clitellum. Segments (18)26-30 ($\bar{x}$=28.1, sd=1.08, n=29). Prostomium glandular, conical. Head pore just anterior to 0/1. Cutaneous gland cells small, in seven to nine rows in preclitellar region, four to six rows behind clitellum, two to three in terminal segments; scarcely visible in some specimens. Clitellum extending over XII-½ or ¾XIII (to about level of setae), cells non-granular, in 34-40 transverse rows. Setae straight or slightly curved distally with a moderate ental hook (Fig. 2A), three per bundle laterally and ventrally in II-XI, absent in XII, two laterally and ventrally from XIII. Setal lengths 36-45 µm in anterior segments, 41-52 µm just behind clitellum, 45-54 µm in terminal segments; lateral setae in XIII-XIV usually smaller and thinner.

Three pairs of pharyngeal glands, first two united dorsally, unlobed, third pair with small ventral lobes (Fig. 2B), usually united dorsally by a narrow bridge of tissue. Gut expanding gradually at 6/7. Oesophageal and intestinal diverticula absent. Chloragocytes small, about 10 across intestine in mounted specimens, with a few small oil droplets in live specimens. Coelomocytes nucleated, 10-20 µm long, round, oval or elongated, sometimes irregular, with fine granules (Fig. 2C). Dorsal vessel originating in XII or XIII; anterior bifurcation at level of setae in IV. Blood colourless. Nephridia from 7/8, cylindrical in postclitellar segments (Fig. 2K), swollen in preclitellar region (Fig. 2J), with rounded preseptale enclosing nephrostome and a short, stout, terminal efferent duct. Brain 80-90 µm in length, nearly twice its maximum width, tapering from about 45-50 µm across posteriorly to about 35 µm anteriorly; both anterior and posterior borders slightly indented (Fig. 2H).

Testes slightly lobed or unlobed, each about ¼ the diameter of worm. Seminal vesicle unpaired, dorsal, confined to XI, occasionally extending into mid X or the anterior part of XII. Sperm funnel very long, in two parts: a glandular, cylindrical part with a corrugated surface, roughly the same diameter throughout its length, 185-340 x 32-38 µm (n=6) with a collar about the same height as width of funnel, attached spermatozoa reddish brown, 54-60 µm, and a thin-walled, non-glandular section about half the length of the glandular part which tapers to the vas deferens as it passes through the septum 11/12 (Fig. 2G). In both live and fixed worms funnels (glandular sections) are equal to nearly twice diameter of worm, or even longer, and are bent around in XI (Fig. 2F). Vasa deferentia narrow, 3-4 µm across, and very long, the two coiled ducts forming compact masses in anterior of XII (Fig. 2F). Penial bulbs on ventral surface of body, small and compact and variable in size, diameter 30-67 µm; vas deferens entering more or less centrally (Fig. 2I). Just anterior to the bulb, or lateral to it in some individuals, a large gland opens separately into a small chamber which also receives the vas deferens (Fig. 2I). The gland is 90-136 µm in length and its proximal part is bulbous, containing many non-staining granules which appear dark-brown by transmitted light in live specimens. The gland is flexible and swings back and forth with movement of the worm. When not fully developed, the gland may be about the same size as the penial bulb. One, occasionally two or three mature eggs at a time. Spermatheca confined to V consisting of a thick-walled ectal duct, 60-76 x 16-21 µm, without glands at pore, and a small ampulla surrounded by a ring of five to seven sessile diverticula, each with four to six spherical cavities in which sperm are arranged in rings (Figs. 2D,E). Ental duct very short, ampulla almost sessile on wall of oesophagus.

Remarks. The species is referred to *Marionina* on the basis of the branching of the anterior blood vessel in IV, a character found only in marine species and a few terrestrial species of *Marionina*, and the shape of the nephridium with nephrostome enclosed in a bulky preseptale and short, stout ectal portion. However, the large gland associated independently with the male pore is unique in enchytraeids. Glandular prostates, opening into the distal part of the vas deferens or into an atrium, i.e. a swollen region of the vas deferens,

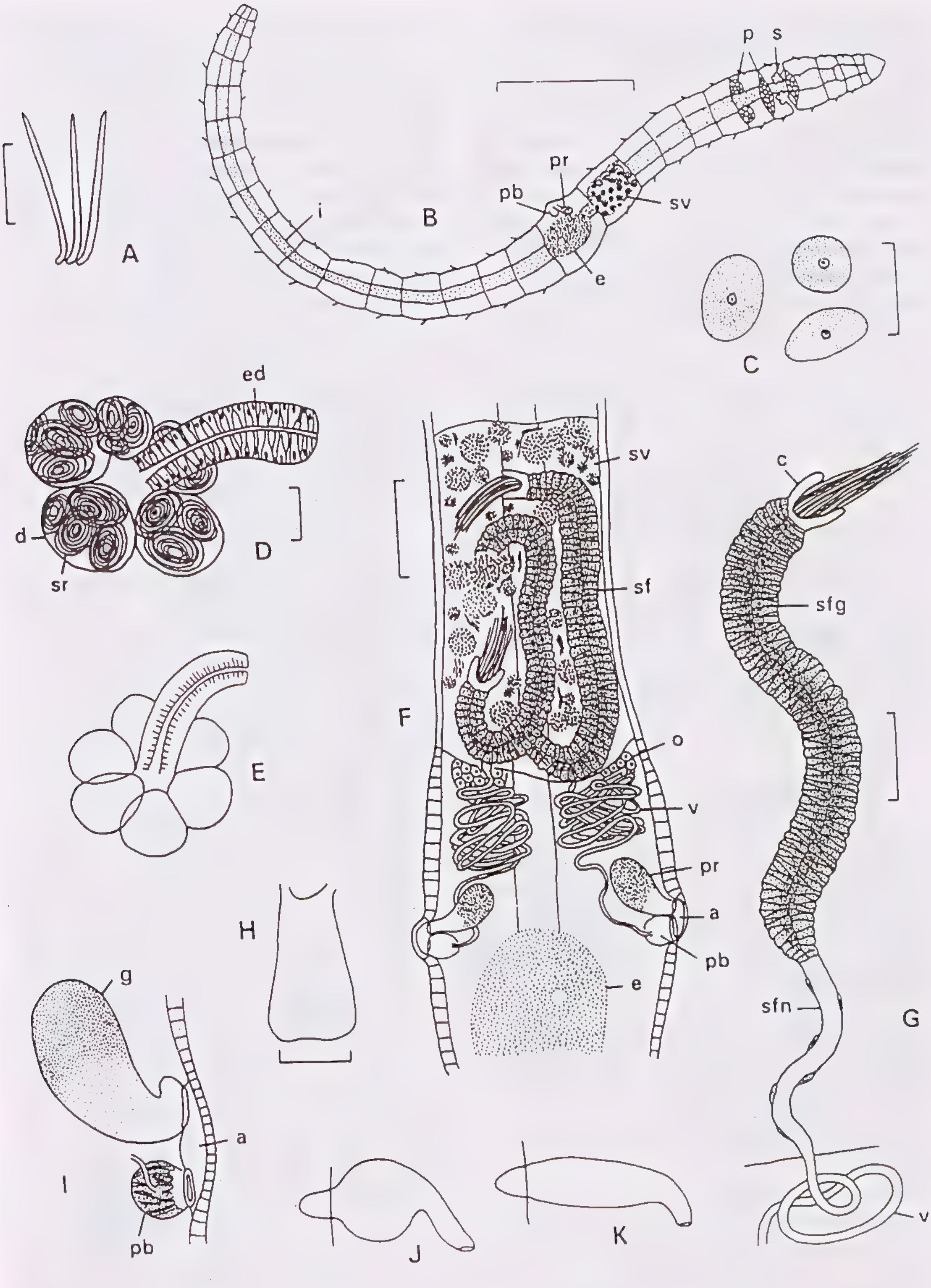

Fig. 2. *Marionina gabiae* sp. n. **A,** anterior setal bundle; **B,** whole specimen; **C,** coelomocytes; **D,** spermatheca; fixed specimen; **E,** spermatheca, live specimen; **F,** segments XI and XII (the vasa deferentia are about twice as long as shown); **G,** sperm funnel; **H,** brain; **I,** penial bulb and gland; **J,** anterior nephridium, fixed specimen; **K,** postclitellar nephridium, live specimen. Scale bars 500 μm (B), 50 μm (F, G, I) and 20 μm (A, C, D, H).

are found in *Mesenchytraeus*, but in *M. gabiae*, the structure appears to open into an epidermal invagination which also contains the opening of the vas deferens. The gland is thus not homologous with the prostates found in *Mesenchytraeus* or in other oligochaete families (Stephenson 1930). Many other features of the reproductive system of *M. gabiae* are shared with *M. waltersi* Healy, 1994, recorded from salt marshes in Georgia, U.S.A., particularly the long, narrow sperm funnel tapering through a non-glandular section to a long vas deferens, and a spermatheca with a very short ental duct and a ring of diverticula around the ampulla. *Marionina waltersi* differs in having sigmoid setae and longer sperm which are not arranged in multiple discrete bundles within the spermathecal diverticula. The arrangement of setae seen in *M. gabiae*, three per bundle in front of the clitellum and two behind, is unusual for *Marionina* and suggests affinities with *Stephensoniella*.

Distribution and habitat. In the banks of mangrove creeks at three localities. Abundant in wet, gravelly deposits at the edge of a small tidal creek (Station 57).

Etymology. Named for Gabi Caswell, in gratitude for her energy and helpful efficiency during the workshop.

Marionina mangle sp. nov.

(Fig. 3)

Type material. HOLOTYPE - NTM Wo0092, stained, whole-mounted specimen, Sadgroves Creek mangrove (Station 50), collector B. Healy, 11 July, 1993. PARATYPES - NTM Wo0093-0094, from the type locality (Stations 19 and 53).

Type locality. Sadgroves Creek, Stations 19, 47, 50 and 53, in the eroding bank of a tidal creek riddled with crab burrows and in mounds of the mudlobster *Thalassina anomala*.

Other material examined. Three whole mounts, BH.DW, from Stations 47 (1), 53 (1), 72 (1). Two live specimens examined (Stations 46 and 97).

Description. Small, slender worms, greyish-white when alive, fixed length 2.9-4.7 mm (n=6), O.08-0.19 mm in diameter but swollen in III-IV (about 0.18 mm) and at the clitellum when a mature egg is present (0.1-0.24 mm), tapering towards the posterior end (Fig. 3A). The longer specimens were also narrower and more stretched and are believed to have been in poor condition at the time of fixation. Segments (19)23-25 (n=6). Prostomium glandular, conical and pointed. Head pore just anterior to 0/1. Cutaneous glands transversely elongated, in about eight rows per segment. Clitellum over XII-¼XIII, clitellar glands rectangular, finely granular or almost transparent, in about 35-40 transverse rows. Setae long and slender, without ental hooks, curved distally with fine points (Fig. 3B). In lateral bundles: four to six in anterior segments, decreasing to two to four in X-XI, four to five behind clitellum; in ventral bundles: four to seven in anterior segments, four in IX-XI, five to six behind clitellum, seven to eight in terminal segments. Setae absent in XII. Setal length 36-44 μm in preclitellar segments, 50-72 μm in postclitellar region, nearly equal within a bundle. In terminal segments their length may exceed diameter of worm. In extended, uncompressed worms, setae in terminal segments lie almost parallel (Fig. 3C) but spread to form a fan when compressed.

Three pairs of pharyngeal glands, united dorsally, without, or with very small, ventral lobes. Oesophageal and intestinal diverticula absent. Transition between oesophagus and intestine gradual in VII, gut swelling at 12/13. Chloragocytes inconspicuous, about six to seven across intestine in mounted specimens. Dorsal vessel originating at 12/13, anterior bifurcation behind brain; ventral vessel unusually large, visible throughout its length. Blood colourless. Coelomocytes nucleated, mainly oval, about twice as long as wide, 16-26 μm in length, a small proportion round, 12-18 μm (Fig. 3D). Brain deeply indented posteriorly, length 90 μm (one specimen) (Fig. 3G). Nephridia not seen.

Testes small and compact (Fig. 3E). Seminal vesicles paired, confined to XI or extending to mid X. Sperm funnel cylindrical, about 80 x 30 μm, with a very short collar, attached sperm at least 40 μm in length (Fig. 3E). Vas deferens long and narrow, 2.5-3 μm in diameter with evenly spaced nuclei, loosely coiled with some loops reaching to 12/13 in most specimens (Fig. 3E). Penial bulb somewhat loose in structure, diameter 40-60 μm, sperm duct entering more or less centrally. One mature egg present at a time. Spermatheca confined to V, with a short, smooth ectal duct without glands at orifice, ampulla almost spherical with four to six cavities in which sperm are arranged concentrically (Fig. 3F). No sperm observed in central lumen. The position of the ampulla close to the oesophagus in mid V indicates the presence of a connection although an ental duct could not be seen.

Remarks. The species is remarkable for the number and length of its setae in relation to the width of the worm. Only two species of marine *Marionina* are known which have numerous (more than five per bundle), curved setae, *M. appendiculata* Nielsen and Christensen, 1959, which is widespread, and *M. paludis* Healy, 1994, known only from salt marshes in Georgia, USA., but in these species the setae are more sigmoid and not as long in posterior segments. A spermatheca without diverticula but with more or less spherical sperm bundles, apparently embedded in the wall, is present in a number of other *Marionina* but none of these has more than two setae per bundle. Nephridia, which are more easily seen in live worms, were indistinguishable in the available material. They are frequently unpaired and reduced in number in small, slender species but it is unlikely that they are absent.

Distribution and habitat. Specimens were taken from seven stations in mangroves at three localities. The species may be widespread in the area but population densities are low. It oc-

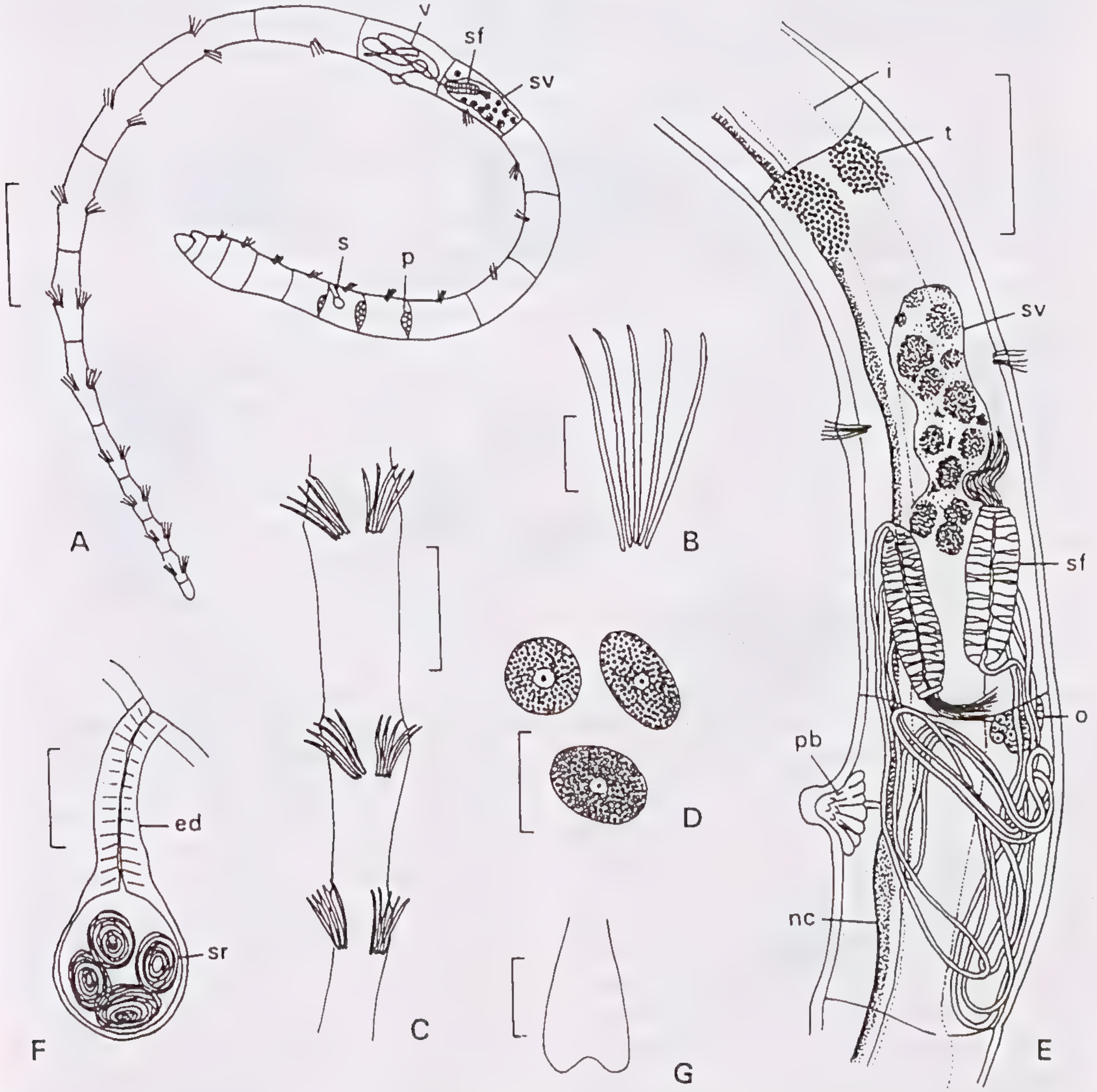

Fig. 3. *Marionina mangle* sp. n. **A,** whole specimen showing swollen anterior and narrow posterior segments (holotype); **B,** setal bundle; **C,** segments XIX-XXI, ventral view; **D,** coelomocytes; E, segments XI and XII, holotype; **F,** spermatheca; **G,** brain. Scale bars 50 µm (A, C, E, G) and 20 µm (B, D, F).

curred in mudlobster mounds and in the banks of creeks. Gut contents consisted almost entirely of diatoms which suggests that they feed on or near the surface.

Etymology. Named for its occurrence in mangroves.

Marionina mandorae sp. nov.
(Fig. 4)

Type material. HOLOTYPE - NTM Wo0095, stained, whole-mounted specimen, Mandorah beach, (Station 3) collector B. Healy, 6 July, 1993. PARATYPES - five whole mounts, NTM Wo0096-0100, and four whole mounts ROMIZ 13252, 13301-13303, from the type locality.

Type locality. Mandorah, Stations 3, 30, 31. Moist sand and decomposing tidal debris consisting of sargassum weed, mangrove leaves and sticks, at high water mark on the beach between the hotel and Mandorah ferry pier.

Other material. Twelve whole mounts, BH.DW, from Stations 3 (4), 20 (1), 30 (4), 31 (2), 42 (1). Five live specimens examined.

Description. Small, whitish worms, fixed specimens swollen in mid region, tapering towards both ends (Fig. 4A). Live length 2-4 mm, diameter 0.16 at VII, 0.19 mm at the clitellum. Fixed length 1.7-3.2 mm ($\bar{x}$=2.3, sd=0.38, n=21), diameter 0.14-0.22 mm in VII, 0.15-0.3 at the clitellum. Segments (19)22-27 ($\bar{x}$=22.9, sd=1.96, n=21). Prostomium glandular, rounded; head

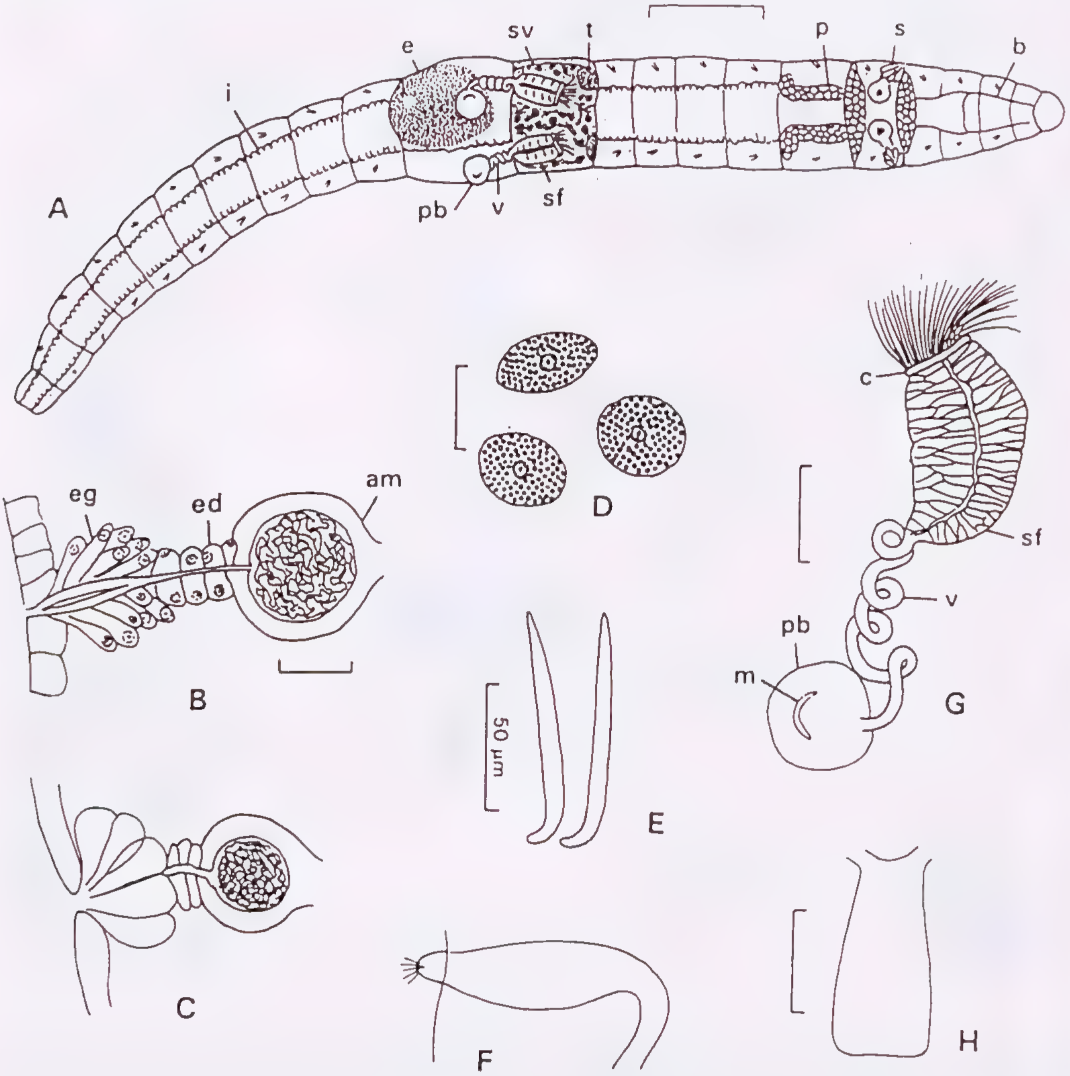

Fig. 4. *Marionina mandorae* sp. n. **A,** whole specimen; **B,** spermatheca, fixed specimen **C,** spermatheca, live specimen; **D,** coelomocytes; **E,** setae; **F,** nephridium; **G,** sperm funnel, vas deferens and penial bulb; **H,** brain. Scale bars 200 µm (A), 20 µm (C, D) and 10 µm (B, E, F).

pore at 0/1. Cutaneous glands rather large, in three rows per segment. Clitellum extending over XII-12/13 or mid XIII, clitellar glands large, without conspicuous granules, arranged in 15-18 transverse rows. Setae straight, with moderate ental hook, two per bundle laterally and ventrally but absent in XII, 36-50 µm in preclitellar region, 26-40 µm behind clitellum (Fig. 4E).

Three pairs of pharyngeal glands, first two united dorsally with small ventral lobes, third pair small, free, with or without ventral lobes (Fig. 4A). Oesophageal and intestinal diverticula absent. Gut widening gradually at 5/6 or 6/7. Chloragocytes large, starting at VI, five to seven across intestine in preclitellar region in mounted specimens, packed with many large (up to 6 µm) and some small oil droplets in live specimens. Coelomocytes nucleated, mostly elliptical, occasionally oval or round, with coarse granules, appearing brown by transmitted light in live individuals, length 16-32 µm (Fig. 4D). Dorsal vessel originating at 12/13, anterior bifurcation at about 3/4. Blood colourless. Nephridium a slightly swollen cylinder with rounded preseptale enclosing the nephrostome and short, stout efferent region (Fig. 4F). Brain about 100 µm long, with rounded posterior border, tapering from about 50 µm across posteriorly to 20-25 µm near its anterior border (Fig. 4H).

Testes somewhat lobed, 70-100 µm in length. Seminal vesicle unpaired, dorsal, extending from 11/12 to 10/11 or mid X. Sperm funnel in one live individual 135 µm in length, about twice as long as wide, equal to about half diameter of worm, with a wide collar of same diameter as funnel and light brown sperm heads. Size of sperm funnel when fixed 60-120 x 44-80 µm (Fig. 4G). Vasa deferentia rather stout, 6-7 µm in diameter, at least partly coiled into spirals, entering penial bulbs laterally (Fig. 4G). Penial bulbs large, 35-40 µm, each occupying about ¼ of diameter of clitellum in mounted specimens. One, rather small, mature egg. Spermatheca confined to V (Fig. 4B,C). Ampulla more or less spherical, with thick wall, sperm in a tangled mass filling lumen. Ental duct short, connecting with oesophagus at about mid V. Ectal duct covered with rounded cells along its length, a circle of larger cells around orifice forming a mass almost as large as ampulla (Fig. 4C).

Remarks. A number of marine species of *Marionina* have been described which have paired, straight setae throughout. Most, like the present species, are small, with a well-developed seminal vesicle and sperm funnel, and a simple spermatheca, without diverticula, in V. *Marionina mandorae* is distinguished from other members of this group by its stout vas deferens wound into a spiral, and large penial bulb, and by the presence of large ectal glands around the spermathecal pore as well as glandular cells along the duct. The irregular arrangement of sperm within the ampulla distinguishes the species from *M. coatesae* Erséus, 1990, also present at Station 3, which also has large glands at the spermathecal orifice but which has rings of sperm embedded in the ampullar wall.

Distribution and habitat. In well drained substrates. In strandline debris with rotting algae and in moist sand beneath, less abundant in eroding banks of mangrove creeks with roots or crab burrows and in the drier mudlobster mounds. Very abundant in decomposing algae at the type locality where the majority of individuals were immature at the time of sampling. Some of these matured in culture allowing verification of their identity. The habitat is an ephemeral one, debris drying out during neap tides in dry weather and it was observed that worms retreated into the moist sand as the surface became dry. The surface sand below tidal debris was completely dry at the other localities visited and no specimens could be found, even at the depths which were still moist, thus it is not known whether the species is as widespread in the area as its abundance at the type locality would suggest.

Etymology. From Mandorah, the type locality.

Marionina tumulicola sp. nov.
(Fig. 5)

Type material. HOLOTYPE - stained whole mount, NTM Wo0088, Sadgroves Creek mangrove (Station 53), collector B. Healy, 11 July 1993. PARATYPES - Three whole mounted specimens from the type localityand station 20, NTM Wo0089-0091.

Type locality. Sadgroves Creek, in the older, well-drained mounds of the mudlobster *Thalassina anomala*, in upper *Rhizophora* and lower *Bruguiera* zones (Stns 20 and 53).

Other material. Two stained whole mounts, BH.DW, from Station 53. Some live material from Stations 46, 81 and 98 examined only briefly.

Description. Small, slender, fragile worms, spotted with silvery white when live due to the presence of refringent coelomocytes. Length of fixed worms 3.0-4.2 mm, diameter 0.070-0.120 mm, 0.10-0.160 mm at clitellum. Segments 27-

30 (n=6). Prostomium glandular, conical but with a rounded tip. Head pore just anterior to 0/1. Cutaneous glands scarcely visible in most specimens, in four to six rows in anterior segments in one individual. In most specimens the body surface was covered with a secretion to which small particles adhered, but no specialised adhesive glands were apparent. Clitellum over XII, occasionally into part of XIII, clitellar region not swollen except when an egg is present; gland cells without visible granules, rectangular, in 28-33 transverse rows. Lateral setae absent. Ventral setae two per bundle in front of the clitellum, one per "bundle" behind, setae absent in II and XII, 26-32 μm, slightly curved with strong ental hook (Fig. 5E).

Only two pairs of pharyngeal glands at 4/5 and 5/6, both small and united dorsally without ventral lobes (Fig. 5A). Oesophageal and intestinal diverticula absent. Gut swelling gradually, or sometimes abruptly, at 5/6. Chloragocytes present from V, six to seven across intestine in mounted specimens. Origin of dorsal vessel intraclitellar, anterior bifurcation behind brain. Blood colourless. Coelomocytes oval, 7-10 μm long, usually with an eccentric nucleus, occasionally round (Fig. 5B). The refringent cells which give the live worm its silvery appearance had largely disintegrated in mounted specimens and their shape and size was not discernible. They contain dense particles and are believed to be larger than the normal type of coelomocytes and are possibly aggregated. They were most abundant in the posterior region. Brain 45-90 μm in length, 1½-2 times longer than wide, tapering anteriorly, deeply indented or cleft on its posterior border (Fig. 5D). Nephridia not seen.

Testes small and compact, ovoid, about 15 μm in length (Fig. 5A); seminal vesicle absent. Sperm funnels small, cylindrical, 16-32 μm in length, with scarcely raised collars (Fig. 5C). Vasa deferentia 1.9-2.3 μm across, short, not coiled, entering small, compact penial bulbs, 21-25 μm long. Ovaries large, often filling anterior part of XII. One egg mature at a time. Spermatheca small, lying almost transversely in anterior part of V (Fig. 5A). Ectal duct stout, with somewhat rugose outer surface, without

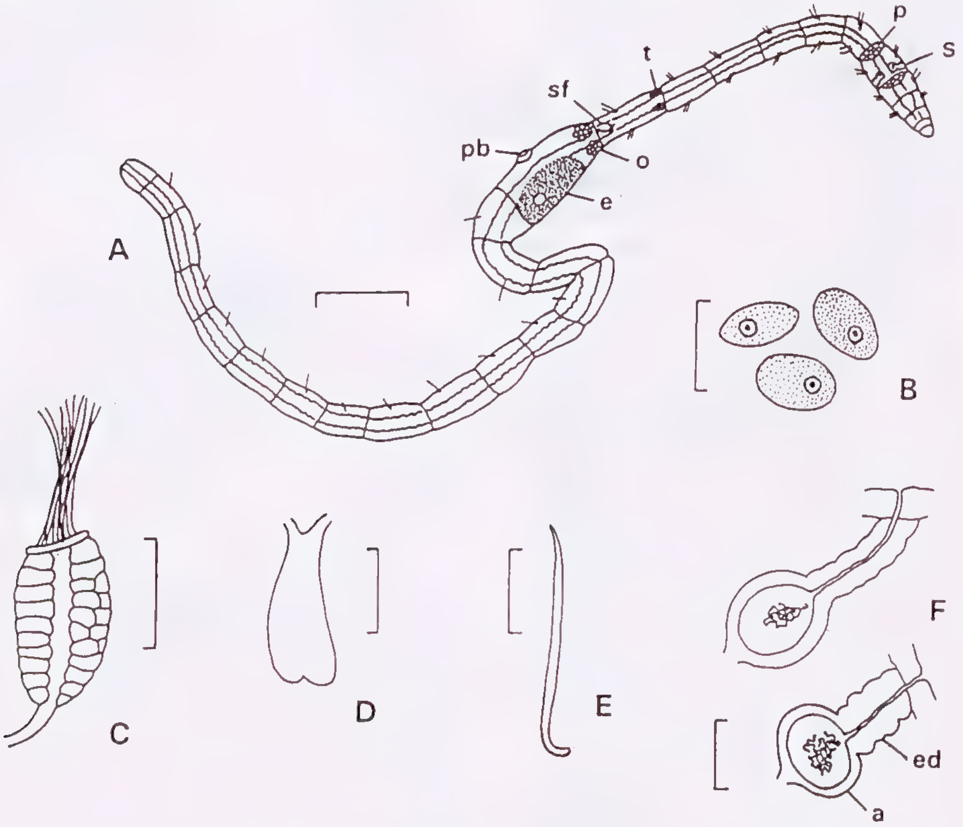

Fig. 5. *Marionina tumulicola* sp. n. **A,** whole specimen, segments I-XI viewed dorsally, XII and postclitellar segments viewed laterally; **B,** coelomocytes; **C,** sperm funnel; **D,** brain; **E,** seta; **F,** spermathecae from two specimens. Scale bars 200 μm (A), 50 μm (E, G, H) and 20 μm (B, C, D).

glands at orifice, 18-20 μm in length, 5-8 μm across. Ampullae nearly spherical, 10-14 μm, thin-walled, with a small amount of tangled sperm in lumen, attached to oesophageal wall just behind septum at 4/5 (Fig. 5F).

Remarks. The description is incomplete due to inadequate material and the small size of some internal organs which made them difficult to distinguish. Confirmation is needed of the origin and branching pattern of the dorsal vessel and the length and position of the vas deferens. A number of marine species of *Marionina* have been described in which lateral setae are entirely absent. Among these, *M. tumulicola* resembles *M. preclitellochaeta* Nielsen and Christensen, 1963 in having only two pairs of pharyngeal glands but the latter species has ventral setae in some preclitellar segments only. The unique features of *M. tumulicola* are the reduction of ventral setae to one per "bundle" in the postclitellar region and the presence of refringent coelomocytes which give live worms their silvery appearance. These cells do not fix well, however, and could easily be missed if only fixed mounts were examined. The lack of information on nephridia may be due to the small size and poor condition of the fixed specimens (see *Marionina mangle*).

Distribution and habitat. Only in mangroves, generally in mounds of the mudlobster. Although only a few specimens were available for the description, others which were in poor condition after extraction were obtained from three localities and an attempted culture did not survive. A number of immature specimens with the same characteristic shape and silvery spots were taken from mudlobster mounds at several localities. The species may thus be quite common in the area. Gut contents consisted of particulate and amorphous organic matter, without fibres.

Etymology. From the Latin, *tumulus* - a mound and *colere* - to inhabit, referring to its occurrence in mudlobster mounds.

Marionina coatesae Erséus, 1990

Marionina coatesae Erséus, 1990:318-319, fig. 26 A-G.

Marionina coatesae - Erséus *et al.* 1990:117-118, fig. 6 A-B; - Coates and Stacey 1993:411, fig. 12, A-C.

Material examined: Two whole mounts: Station 3, NTM Wo0108; Station 91, BH.DW. No live material examined.

Brief description of new material. Fixed length 3.4, 3.8 mm, diameter at VII, 0.17-0.23 mm, at the clitellum 0.23-0.25. Segments 28. Setae straight, 42-50 μm in length, two in all bundles, absent in XII. Clitellum over XII-½XIII, gland cells in transverse rows. All three pairs of pharyngeal glands with ventral lobes, first two united dorsally, third pair free. Dorsal vessel origin intraclitellar, anterior bifurcation behind brain. Coelomocytes abundant 18-24 μm in length, circular or ovoid, finely granular with prominent nucleus. Copulatory gland on the nerve cord in XIV in one specimen. Testes large, filling anterior quarter of XI, seminal vesicle unpaired, extending from 10/11 into anterior of XII (one specimen). Sperm funnel equal to two- thirds or three-quarters diameter of worm, about 1½ times longer than wide; vas deferens long and narrow, 5-6 μm in diameter, coiled into a tight mass in posterior of XII. Spermathecal ampulla nearly spherical with rings of sperm embedded in a thick wall and small amounts of loose sperm in the lumen. Ectal duct short with elongate gland cells, almost as long as duct, around orifice.

Remarks. The present material conforms with previous descriptions except for the dimensions and position of the vas deferens which is much narrower than that described in Hong Kong specimens (Erséus 1990) and situated in the posterior part of XII instead of in the anterior part as is more usual in enchytraeids. The positioning of the duct coils may, however, be the result of compression. The spermatheca resembles that figured by Erséus (1990) with elongate glands masking the duct, rather than the shorter glands spread along the duct described for specimens from Western Australia (Coates and Stacey 1993).

Distribution and habitat. North and south China; Rottnest Island, Western Australia. Intertidal coarse sand, occasionally mixed with algal debris. In the present survey, from tidal debris at high water spring tide level and among mangrove roots in the bank of a tidal creek.

Marionina nevisensis Righi and Kanner, 1979

Marionina achaeta nevisensis Righi and Kanner, 1979: 65-66, figs 52-57.

Marionina nevisensis: Coates, 1983b: 825-826, figs 5-7; 1990: 32-33, fig. 10 A-C; Erséus 1990: 320-321, fig. 27 A-B; Erséus *et al.* 1990:

118-119, fig. 7; Coates and Stacey 1993: 411, fig. 13 A-C.

Material examined. Two whole mounts, NTM Wo0109-0110, (Stations 61 and 70), two whole mounts BH.DW (Station 61). No live material examined.

Brief description of new material. Slender, rather stiff worms with thick cuticle, sometimes silvery white when alive. Fixed length 3.0-5.4 mm, diameter 0.17 mm, segments 33-37 (n=4). First two pairs of pharyngeal glands united dorsally, third pair separate, voluminous. Clitellum over XII-XIII, gland cells not in transverse rows. Coelomocytes ovoid or spindle-shaped, 12-22 μm in length. In two specimens there were also round coelomocytes with coarse granules, mainly in the posterior region, which probably gave the live worms their white colour. Dorsal vessel originating at 14/15. Sperm funnel 130-140 x 44-80 μm, two to three times longer than wide, with collar of about same diameter. Seminal vesicle from 9/10 to anterior part of XIII. Vas deferens 4-6 μm in diameter, penial bulb 36-40 μm long. Egg sac with three eggs in XIII, XIV and XV. Spermatheca with a nearly spherical ampulla in which sperm tend to adhere in about four long bundles, each bent around into an S-shape. Ectal duct stout with glands near external opening only.

Remarks. Size and segment number and proportions of the sperm funnel and spermatheca are as in other descriptions (Righi and Kanner 1979; Coates 1983b; Erséus 1990). The presence of coarsely granular coelomocytes in addition to the normal kind was not mentioned by other authors. Their occurrence in only some individuals of a population is not unusual in achaetous species of *Marionina* (personal observation). The ectal duct of the spermatheca did not appear to be covered with gland cells as described by Coates (1983b:fig. 7) and Erséus (1990: fig. 27, B) but showed only large glands near the orifice, resembling more closely that figured by Righi and Kanner (1979:fig. 53).

Distribution and habitat. Nevis Island, Leeward Islands, Caribbean; British Columbia, Canada; Hong Kong, China; Albany and Rottnest Island, Western Australia. In intertidal coarse sand, especially shelly deposits, and in subtidal shelly sand. In the present survey, from the exposed, shelly bed of a mangrove creek and sandy silt in the eroding bank of a creek on the shore.

DISCUSSION

A fairly comprehensive survey of habitats at 15 localities has yielded only eight species of enchytraeid. Comparable numbers have been recorded from similar surveys in Bermuda (Lasserre and Erséus 1976) and China (Erséus 1990; Erséus *et al.* 1990), and from Western Australia where only four species of *Marionina* and one *Lumbricillus* were recorded from mid and upper intertidal habitats (Coates 1990; Coates and Stacey 1993). Many more species have been recorded from an equivalent range of habitats on northern cold-temperate shores, e.g. the Baltic (Knöllner 1935), Wales (Tynen 1972) and British Columbia (Coates and Ellis 1981). A higher species diversity was expected in the present survey in view of the large tidal range and the wide variety of habitats sampled, including mangroves which had not previously been investigated.

Only two genera are recorded: *Stephensoniella* which is largely confined to warm climates and was not recorded from Western Australia (Coates 1990; Coates and Stacey 1993), and *Marionina* which appears to be well-represented in warm regions. The absence of *Lumbricillus* which, together with *Enchytraeus*, dominates the enchytraeid fauna of strandline debris in the northern temperate zone and is common on Antarctic shores, was expected as it rarely extends into warm waters, with the exception of the very tolerant species *Lumbricillus lineatus*, reported from Western Australia (Coates 1990). *Enchytraeus,* which has been recorded from several tropical localities, was also absent. *Enchytraeus albidus* was recorded by Michaelsen (1907) from Western Australia but was not found in the region during more recent surveys (Coates 1990; Coates and Stacey 1993) and no species of *Enchytraeus* have been recorded from the small number of terrestrial habitats investigated on the continent, including a few during this survey.

Only two of the species in Darwin Harbour have previously been recorded from Australia: *Marionina coatesae* (Coates and Stacey 1993) and *M. nevisensis* (Coates 1990; Coates and Stacey 1993). Both were reported from China (Erséus 1990; Erséus *et al.* 1990) and *M. nevisensis* was described from the Caribbean, they are thus characteristic of warm regions. *Stephensoniella marina* and *S. trevori*, new records for Australia, are probably widespread on tropical beaches but can also extend into temperate regions, e.g. Canada (Coates and Ellis 1981). Three of the four newly described species are from mangroves or associated with mangroves, a formation for which there are no previous records of enchytraeids. A notable absence from Darwin Harbour is *Marionina appendiculata* Nielsen and Christensen, 1959, a widespread species characteristic of muddy habitats, which was present in Western Australia (Coates 1990) and has been recorded from warm regions of the USA (Healy 1989, 1994).

The absence of enchytraeids from most wet deposits confirms earlier impressions about their ecological requirements. In hot climates, it appears that they need well-drained substrates and do not tolerate saturated conditions unless there is a constant supply of oxygen (Healy 1989; Giere and Pfannkuche 1982). They were not found, for example, in the the surface mud of mangroves, nor in the beds of creeks except where there was a strong tidal flow. The greatest numbers of enchytraeids, and also the highest diversity, occurred in and under strandline debris consisting of algae and leaves, as long as it remained moist. Such conditions were only present in a few places at the time of sampling and are probably temporary during the dry season. Numbers, and even species, could well increase during the wet season as they do in other habitats in the tropics (Thambi and Dash 1973). The only other productive habitats were the banks of creeks where capillary water maintains moist conditions and where crab burrows ensure good drainage, and the older mounds of the mudlobster, *Thalassina anomala.* These mounds were common throughout the mangroves. They consist of mud, excavated by the mudlobster from below the mounds. In the upper mangrove zones they are semi-permanent structures reaching 30 cm in height. Other invertebrates invade the mounds, including polychaetes and crabs which rework the mud creating numerous burrows which improve drainage and speed decomposition. Beneath an outer crust, which may become dry during neap tides, the mound is fibrous, remaining moist but well-drained, and is rich in decomposing organic matter. Enchytraeids were mainly found in the drier mounds around high water neap tide level while few were present at higher levels where the mounds tend to dry out or towards mid tide level where they were wetter and subject to more frequent tidal flooding. *Marionina tumulicola* was almost entirely confined to mudlobster mounds, suggesting specialisations for a unique set of conditions.

The scarcity of enchytraeids in sandy beaches, except near low tide level (*Grania* and *Randidrilus*), is believed to be due to a combination of high temperature and high salinity, the latter reaching over 100‰ in shallow upper beach pools. There are no data on the tolerance of marine enchytraeids to such conditions but the microdistribution of the meiobenthic tubificid *Aktedrilus monospermathecus* Knöllner, 1935, living in the subtropical beaches of Bermuda was restricted to layers with moderate temperatures and relatively stable salinity, and by preference for well oxygenated sand and avoidance of unusually high alkalinity (Giere 1977), conditions which may not always be present on warm beaches. Giere and Pfannkuche (1978) have proposed that whereas in boreal climates the habitat fluctuations for many environmental factors apparently lie well within the tolerance limits for oligochaete populations so that other factors such as food may be limiting, in subtropical climates the maximal oscillation of environmental parameters, particularly temperature and salinity, are shifted close to the tolerance limits of the same species and these factors thus become limiting. This, if true, would also apply to tropical beaches. The abundance of soldier crabs and other fauna on the beaches of Darwin Harbour precludes the likelihood that enchytraeids are limited here by a shortage of organic matter, thus other environmental limitations are probably operating.

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THE MARINE TUBIFICIDAE (OLIGOCHAETA) OF DARWIN HARBOUR, NORTHERN TERRITORY, AUSTRALIA, WITH DESCRIPTIONS OF FIFTEEN NEW SPECIES.

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ABSTRACT

Thirty-seven species of Tubificidae are reported from the Darwin area, none of which has been recorded from the Northern Territory before, but the diversity of the 185 mature specimens collected indicates that the actual number of species in the area is significantly higher. Fifteen new species are described: *Heterodrilus rapidensis* sp. n., *Ainudrilus mediocris* sp. n., *A. brendae* sp. n., *A. piliferus* sp. n., *Albanidrilus coxensis* sp. n., *A. caswellae* sp. n., *Coralliodrilus improvisus* sp. n., *C. hanleyi* sp. n., *Bathydrilus ampliductus* sp. n., *Duridrilus darwinensis* sp. n., *Smithsonidrilus ludmillae* sp. n., *S. arduus* sp. n., *S. convexus* sp. n. and *Limnodriloides lateroporus* sp. n. from marine habitats, and *Ainudrilus stagnalis* sp. n. from a freshwater billabong. The other species, except for an unnamed *Bathydrilus*, are all known from other parts of the Indo-West Pacific region. Taxonomic notes are given for most of them. In Darwin Harbour, tubificids appear restricted to small patchy habitats of largely coarse, organically enriched sediments associated with intertidal creeks, reefs and rock pools, and to muddy sand in mangroves.

Keywords: Tubificidae, Oligochaeta, taxonomy, new species, Indo-West Pacific, marine biogeography, ecology.

INTRODUCTION

Previous studies of marine Tubificidae of Australia have been confined to Queensland (Jamieson 1977; Erséus 1979a, 1981a-b, 1984a; Erséus and Jamieson 1981), New South Wales and Victoria (Erséus 1990a), and Western Australia (Erséus 1990b, 1993). Tubificids, both in terms of individuals and number of species, are particularly numerous in the sandy habitats associated with reefs and lagoons of the Great Barrier Reef (Erséus 1981a-b, 1984a), and on intertidal platforms such as those of Rottnest Island in Western Australia (Erséus 1993). Furthermore, several species occur on the Great Barrier Reef as well as in Western Australia (Erséus 1993), which suggests a continuous distribution of these (largely tropical) taxa along the northern coasts of Australia.

Darwin Harbour (Northern Territory), with its extensive sand flats, appeared to be a promising area for the collection of tubificid worms, when I joined the Sixth Marine Biological Workshop at Mandorah, near Darwin, in July 1993. This area was expected to provide many of the truly tropical tubificids of the Indo-West Pacific marine fauna.

The tubificid material collected during the workshop comprises only 185 sexually mature specimens, but it contains as many as 37 species, all recorded from the northern coast of the Australian continent for the first time. Despite the limited material it has been possible to recognize and name 15 of the species as new taxa. All except one species are marine.

Materials and methods. All specimens studied were collected during the workshop at Mandorah (July 1993). Oligochaetes were ex-

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tracted from intertidal and subtidal (and one freshwater) sediment samples (see List of Stations below). Enchytraeidae from these samples are treated separately (Coates and Stacey 1996; Healy and Coates 1996).

The samples (each up to about 5 litres of sediment) from stations visited by K. A. Coates or the author were repeatedly stirred with habitat water (mostly seawater) and the organic suspensions decanted into a fine-mesh sieve (250-350 µm). Samples collected by B. Healy were either treated in the same way or used for wet funnel extraction (see Healy and Coates 1996, for details).

Live oligochaetes were sorted under a dissecting microscope. With a few exceptions, only sexually mature specimens were fixed, in either Bouin's or Kahle's fluids. After about one day in the fixative, they were transferred into 70% ethanol. The anterior ends (including the genital regions) of a few worms were longitudinally sectioned and stained with Azan, but most individuals were stained with paracarmine, cleared in xylene and mounted whole in Canada balsam. When not stated otherwise, material listed in the Systematic Account refers to whole-mounted specimens.

Some material of most species (including all holotypes) is deposited in the Museum and Art Gallery of the Northern Territory (NTM), Darwin, N.T., Australia, while other material, including several paratypes, is in the Swedish Museum of Natural History (SMNH), Stockholm, Sweden.

The descriptions of the species are based on the fixed, somewhat contracted and, if whole-mounted, compressed worms. Segment numbers are denoted by Roman numerals.

List of stations. Three sources of material were available at the workshop: (1) sediment samples collected by, or brought in by other participants for the exclusive use of, the author (Stations 1-42); (2) samples collected by Dr Kathryn A. Coates (Stations KAC-6 through KAC-51), and (3) samples collected by Dr Brenda Healy (Stations BH-28 through BH-69). The list excludes stations that did not yield any Tubificidae. All stations are from the surroundings of Darwin, Northern Territory. The tubificid species encountered are listed for each station.

1. Outer end of Woods Inlet, Oak Point (Cox Peninsula), 12°27.1'S, 130°45.9'E, upper intertidal sand flat, heterogeneous, largely coarse sand, with some shells, 5 July 1993; *Pectinodrilus heronensis.*

3. N end of flat at Lee Point (N of Darwin), 12°19.7'S, 131°53.0'E, reef platform in lower intertidal zone, small rock pool with gravelly sand, 6 July 1993; *Heronidrilus bihamis, H.* cf. *gravidus, Smithsonidrilus convexus* sp. n., *S. irregularis, Limnodriloides rubicundus.*

4. Flat at Lee Point (N of Darwin), 12°20.0'S, 131°52.8'E, outer part of mid-intertidal reef, patches of heterogeneous sand between boulders, 6 July 1993; *Pacifidrilus aquilinus, Bathydrilus* sp., *Olavius clavatus, Limnodriloides biforis.*

6. Outer end of Woods Inlet, inside N end of reef S of Oak Point (Cox Peninsula), 12°27.4'S, 130°46.0'E, lower intertidal, sand, gravel and pebbles, 7 July 1993; *Albanidrilus caswellae* sp. n., *Pacifidrilus aquilinus.*

8. Outer end of Woods Inlet, inside (rubble) reef S of Oak Point (Cox Peninsula), 12°27.4'S, 130°46.0'E, mid-intertidal, medium to coarse sand, sediment black with strong smell of H_2S at a few cm depth below surface, 7 July 1993; *Olavius clavatus.*

9. Outer end of Woods Inlet, outer end of creek pond about 1 km S of Mandorah (Cox Peninsula), 12°27.5'S, 130°45.8'E, 0.2 m, muddy coarse, poorly oxygenated sand near mangroves, 7 July 1993; *Limnodriloides lateroporus* sp. n.

10. Rocky intertidal flat about 200 m W of East Arm boat ramp (East Arm, Darwin Harbour), 12°29.4'S, 130°53.7'E, lower intertidal, coarse sand between boulders, 8 July 1993; *Pacifidrilus aquilinus, Coralliodrilus hanleyi* sp. n.

11. Point N of East Arm boat ramp, opposite North Shell Island (East Arm, Darwin Harbour), 12°29.4'S, 130°53.7'E, lower intertidal, coarse shelly sand, 8 July 1993; *Heterodrilus keenani, H. claviatriatus, Pacifidrilus aquilinus.*

13. Reef S of point, W of East Arm boat ramp (East Arm, Darwin Harbour), 12°29.7'S, 130°53.5'E, lower intertidal, coarse sand, gravel and pebbles, 8 July 1993; *Heterodrilus claviatriatus.*

14. Sand bar on outer side of reef, opposite North Shell Island, W of East Arm boat ramp (East Arm, Darwin Harbour), 12°29.7'S, 130°53.5'E, lower intertidal, coarse sand and gravel, 8 July 1993; *Pacifidrilus aquilinus.*

15. Point at Nightcliff, W of Rapid Creek (N of Darwin), 12°25'S, 130°51'E, mid-intertidal rock pool, heterogeneous sand between boulders, 9 July 1993; *Smithsonidrilus minusculus, S. irregularis, Limnodriloides lateroporus* sp. n.

16. Creek stream (tidal seawater) in intertidal flat at Rapid Creek, Nightcliff (N of Darwin), 12°25'S, 130°51'E, mid-intertidal, coarse sand and gravel with some filamenteous green algae on top, 9 July 1993; *Heterodrilus rapidensis* sp. n., *Albanidrilus caswellae* sp. n.

18. E end of Imaluk Beach (N shore of Cox Peninsula), 12°25.8'S, 130°44.2'E, lower intertidal rock pool with corals, 0.5 m deep, gravel, coarse sand and silt, 10 July 1993; *Duridrilus piger, Tectidrilus arabicus.*

20. Outer end of reef at West Point (Cox Peninsula), 12°26.2'S, 130°46.0'E, lower intertidal rock pool, mat of filamentous, calcareous algae, 11 July 1993 (substrate collected by U. Jondelius); *Heterodrilus claviatriatus.*

21. As Station 8, but fine to medium sand, reduced layer close to sediment surface, 11 July 1993; *Olavius clavatus, Limnodriloides lateroporus* sp. n.

22. West Point (Cox Peninsula), 12°26.2'S, 130°46.0'E, lower intertidal, crevice with sand, gravel and pebbles under rocks, 11 July 1993; *Albanidrilus wellsi.*

23. Outer reef at West Point (Cox Peninsula), 12°26.2'S, 130°46.0'E, large rock pool in lower intertidal zone, patches of coarse sand, 11 July 1993; *Smithsonidrilus arduus* sp. n.

25. As Station 22, but lower intertidal rock pools, coarse, largely calcareous sand, 11 July 1993; *Heronidrilus bihamis, Albanidrilus wellsi.*

26. About 2 km E of Charles Point (Cox Peninsula), 12°23.3'S, 130°38.3'E, 1 m below LWM, sand patch between coral heads, heterogeneous sand with gravel and shells, 12 July 1993 (sediment collected by G. Edgar); *Heterodrilus claviatriatus.*

27. Small tidal creek in Ludmilla Creek area (N of Darwin), 12°24.7'S, 130°50.1'E, intertidal coarse, shelly sand, 12 July 1993; *Paupidrilus breviductus, Jamiesoniella athecata, Limnodriloides lateroporus* sp. n.

29. Shallow pool in tidal mudflat, adjacent to main creek, Ludmilla Creek (N of Darwin), 12°24.7'S, 130°50.1'E, muddy fine sand, 12 July 1993; *Smithsonidrilus ludmillae* sp. n., *Limnodriloides biforis.*

30. Middle of main creek in tidal mudflat, Ludmilla Creek (N of Darwin), 12°24.7'S, 130°50.1'E, gravel and fine sand, rich in brachiopods (*Lingula* sp.), 12 July 1993; *Limnodriloides rubicundus.*

31. Small tidal creek in upper part of mangroves area, Ludmilla Creek area (N of Darwin), 12°24.7'S, 130°50.1'E, medium to coarse, shelly sand, salinity about 40 ppt, 12 July 1993; *Doliodrilus diverticulatus, Limnodriloides rubicundus.*

32. "Grab Station D87", 12°32.3'S, 131°49.2'E, 5 m, sand collected (using a van Veen grab) by Marine Ecology Unit, NTM, 12 July 1993; *Duridrilus piger, D. darwinensis* sp. n.

33. Same as Station 1, but 14 July 1993; *Pectinodrilus heronensis.*

34. Large tidal creek running parallel to beach, outer part of Woods Inlet, about 1 km S of Mandorah (Cox Peninsula), 12°27.5'S, 130°45.8'E, sand, gravel and shells, 14 July 1993; *Heterodrilus rapidensis* sp. n., *Albanidrilus coxensis* sp. n., *Pacifidrilus aquilinus.*

36. W of N end of Weeds Reef, West Arm (Darwin Harbour), 12°29.4'S, 130°47.5'E, 1 m below LWM, fine to medium sand, 15 July 1993 (sediment coll. by G. Edgar); *Duridrilus pastoralis, Smithsonidrilus arduus* sp. n.

37. As Station 36, but at 9 m, medium sand, 15 July 1993 (sediment coll. by G. Edgar); *Duridrilus pastoralis.*

38. W of South Shell Island, East Arm (Darwin Harbour), 12°29.9'S, 130°53.0'E, 2 m below LWM, silty coral rubble and coarse coral sand, 15 July 1993 (sediment coll. by G. Edgar); *Duridrilus piger.*

39. As Station 34, but 16 July 1993; *Pacifidrilus aquilinus.*

40. Near large tidal creek running parallel to beach, outer part of Woods Inlet, about 1 km S of Mandorah (Cox Peninsula), 12°27.5'S, 130°45.8'E, intertidal "pool" created by a round piece of junk buried in sand, sand and gravel, 16 July 1993; *Coralliodrilus improvisus* sp. n.

41. Same as Stations 34 and 39, but further downstream in creek (to the south), intertidal gravel and coarse sand, with tufts of green algae, 16 July 1993; *Pectinodrilus multiplex, Coralliodrilus improvisus* sp. n..

42. Billabong, connected by freshwater stream to Stevens Creek, West Arm (Darwin Harbour), 12°38.0'S, 131°43.2'E, sand bank at edge, fine sand, 15 July 1993; *Ainudrilus stagnalis* sp. n.

KAC-6. S side of rock outcrops, Lee Point (N of Darwin), 12°20.0'S, 131°53.0'E, intertidal silt and sand, reduced about 2 cm below surface, 6 July 1993; *Limnodriloides biforis.*

KAC-19. Rocky island off shoal, 200 m W of East Arm boat ramp, near North Shell Island

(East Arm, Darwin Harbour), 12°29.4'S, 130°53.7'E, lower intertidal, coarse sand and shell, sheltered from sea, salinity of pooled water in sediments 40‰, 8 July 1993; *Pacifidrilus aquilinus*.

KAC-27. Rock spit at point at Nightcliff, W of Rapid Creek (N of Darwin), 12°25'S, 130°51'E, intertidal coarse sediments in crevices, salinity 36‰, 9 July 1993; *Olavius clavatus*.

KAC-35. Reef at West Point (Cox Peninsula), 12°26.2'S, 130°46.0'E, intertidal rock pools, 5-10 cm deep, with fish, crabs and few coral heads, coarse rubble and silt, salinity 37‰, 11 July 1993; *Heterodrilus claviatriatus*.

KAC-36. As KAC-35, but pools low in intertidal, with coarse mineral sand, rounded laterite pebbles and silt, salinity 37‰, 11 July 1993; *Pacifidrilus aquilinus*.

KAC-37. As KAC-35 and -36, but shallow pools about 2.2 m above MLW, shell and quartz sand, salinity 37‰, 11 July 1993; *Heterodrilus claviatriatus, Pacifidrilus aquilinus*.

KAC-44. Upper edge of reef at Ludmilla Creek (N of Darwin), 12°24.7'S, 130°50.1'E, intertidal pool, silt and sand sediments and compact shell debris, laterite covered with oysters, 12 July 1993; *Bathydrilus ampliductus* sp. n., *Smithsonidrilus ludmillae* sp. n., *S. irregularis, Limnodriloides rubicundus, L. biforis, L. lateroporus* sp. n.

KAC-51. Inside reef at West Point (Cox Peninsula), 12°26.2'S, 130°46.0'E, pockets of coarse sand, shell, pebble sediments with silt, near daily lower high water line, about 4.8 m above MLW, patchy reduction of sediments to within 1.5 cm of surface, wet, 16 July 1993; *Heronidrilus* cf. *gravidus*.

BH-28. Upper middle shore at West Point (Cox Peninsula), about 12°26'S, 130°46'E, gravel and coarse sand in rock crevices, 8 July 1993; *Bathydrilus ampliductus* sp. n.

BH-47. In mangrove, Sadgroves Creek (E of Darwin), vertical bank of main creek, riddled with crab burrows, firm, fibrous mud, brownish at surface, dark grey below, 11 July 1993; *Ainudrilus mediocris* sp. n.

BH-51. As Station BH-47, but brown algal scum on surface of mud in *Avicennia* zone near creek, 11 July 1993; *Ainudrilus mediocris* sp. n., *A. brendae* sp. n., *A. piliferus* sp. n., *Doliodrilus diverticulatus*.

BH-53. As BH-47 and -51, but from a dry mudlobster mound in lower *Bruguiera* zone, sample from outer crust and lining of main burrow, 11 July 1993; *Ainudrilus mediocris* sp. n.

BH-54. Just above beach at Ludmilla Creek (N of Darwin), bank of small stream draining mangrove, eroding edge with small crab burrows, rich in fibre, and with black patches under surface, 12 July 1993; *Doliodrilus diverticulatus, Limnodriloides fraternus*.

BH-57. Upper mangrove at Ludmilla Creek (N of Darwin), wet, silty gravel at edge of small creek, salinity of creek water 40‰, 12 July 1993; *Paupidrilus breviductus*.

BH-60. Mangrove, Woods Inlet (Cox Peninsula), shelly, gravelly mud at edge of main creek, lumpy and dark with some crab burrows, 13 July 1993; *Ainudrilus mediocris, Paupidrilus breviductus, Limnodriloides fraternus*.

BH-61. As Station BH-60, but dry bed of small stream in *Rhizophora* zone, subject to occasional tidal flooding, moist, gravelly mud with roots, rich in organic matter, 13 July 1993; *Paupidrilus breviductus*.

BH-69. At Mandorah, Woods Inlet (Cox Peninsula), slope facing creek, just below last high water, ground water level at 30 cm, 14 July 1993; *Ainudrilus mediocris*, sp. n. *Pectinodrilus heronensis, P. molestus*.

Abbreviations used in the figures. a, atrium; **aa**, atrial ampulla; **ad**, atrial duct; **cs**, copulatory sac; **epr**, entrance of prostate gland; **fp**, female pore; **gcs**, gland associated with copulatory sac; **lcs**, lateral lobe of copulatory sac; **lmb**, lateral lobe of male bursa; **m**, muscles; **mb**, male bursa (unpaired); **mf**, male funnel; **mp**, male pore; **o**, oesophagus; **od**, oesophageal diverticulum; **p**, penis; **pp**, pseudopenis; **ppa**, prostatic pad; **pps**, pseudopenial sac; **pr**, prostate gland; **pr 1**, anterior prostate gland; **pr 2**, posterior prostate gland; **ps**, penial seta; **s**, spermatheca; **sv**, spermathecal vestibule; **sz**, spermatozeugma; **vd**, vas deferens.

List of species.

Rhyacodrilinae
- *Heronidrilus bihamis* Erséus and Jamieson
- *Heronidrilus* cf. *gravidus* Erséus
- *Heterodrilus keenani* Erséus
- *Heterodrilus claviatriatus* Erséus
- *Heterodrilus rapidensis* sp. n.
- *Ainudrilus mediocris* sp. n.
- *Ainudrilus stagnalis* sp. n.
- *Ainudrilus brendae* sp. n.
- *Ainudrilus piliferus* sp. n.
- *Paupidrilus breviductus* Erséus

Phallodrilinae
- *Albanidrilus wellsi* (Erséus)
- *Albanidrilus coxensis* sp. n.
- *Albanidrilus caswellae* sp. n.
- *Jamiesoniella athecata* Erséus
- *Pectinodrilus heronensis* (Erséus)
- *Pectinodrilus molestus* (Erséus)
- *Pectinodrilus multiplex* (Erséus)
- *Pacifidrilus aquilinus* (Erséus and Davis)
- *Coralliodrilus improvisus* sp. n.
- *Coralliodrilus hanleyi* sp. n.
- *Bathydrilus ampliductus* sp. n.
- *Bathydrilus* sp.
- *Duridrilus piger* Erséus
- *Duridrilus pastoralis* Erséus
- *Duridrilus darwinensis* sp. n.
- *Olavius clavatus* (Erséus)

Limnodriloidinae
- *Doliodrilus diverticulatus* Erséus
- *Tectidrilus arabicus* Erséus
- *Smithsonidrilus minusculus* (Erséus)
- *Smithsonidrilus ludmillae* sp. n.
- *Smithsonidrilus arduus* sp. n.
- *Smithsonidrilus convexus* sp. n.
- *Smithsonidrilus irregularis* (Erséus)
- *Limnodriloides rubicundus* Erséus
- *L. biforis* Erséus
- *L. fraternus* Erséus
- *L. lateroporus* sp. n.

SYSTEMATIC ACCOUNT

Family TUBIFICIDAE
Subfamily Rhyacodrilinae
Genus *Heronidrilus* Erséus and Jamieson, 1981

Heronidrilus bihamis Erséus and Jamieson, 1981

Heronidrilus bihamis Erséus and Jamieson, 1981: 107-108, fig. 6. - Erséus 1984b: 140, fig. 3; - Erséus 1990a: 276; - Erséus 1990b: 47-48; - Erséus 1990c: 272; - Erséus and Davis 1989: 75, fig. 1A; - Erséus et al. 1990: 112, fig. 2F-H. - Erséus 1993: 337-338, fig. 1A.

New material. NTM Wo 0006-0008, 3 specimens from Station 3. SMNH Main coll. 1414-1416, 3 specimens: 2 from Station 3, 1 from Station 25.

Remarks. This widely distributed Indo-Pacific species has very characteristic penial setae (two bundles, each with two setae located 'heel to heel'), and it has been described several times before (references above). The specimen from Station 25 is not fully mature (its penial setae and genitalia only partly developed), but all individuals from Station 3 conform to earlier descriptions.

One additional specimen of *Heronidrilus* from Station 3, plus one from another site, both with well developed clitellum and mature eggs, lack spermathecae and have rudimentary male ducts. These worms are referred to as *Heronidrilus* cf. *gravidus* below.

Distribution and habitat. Northern Territory (new record), Queensland, Victoria, Western Australia, China, Hawaii. Intertidal and subtidal sands, to at least 70 m depth.

Heronidrilus cf. *gravidus* Erséus, 1990

Heronidrilus gravidus Erséus, 1990d: 248-249, fig. 3.

New material. SMNH Main coll. 1417, sectioned specimen from Station 3. SMNH Main coll. 1418, specimen from Station KAC-51.

Brief description of new material. Length of whole-mounted worm, 12.6 mm, 67 segments. Prostomium triangular. Clitellum extending over posterior half of X, all of XI and anterior 2/3 of XII. Setae up to about 65 μm long, three to four per bundle anteriorly, one to two per bundle in postclitellar segments. Setae bifid with small upper tooth. A penial seta (possibly single-pointed) present near male pore at one side of sectioned specimen; otherwise absent. Male pores inconspicuous, in line with ventral setae, posteriorly in XI. Testes present, but no developing or mature sperm observed. Ciliated sperm funnels present, but rest of male ducts rudimentary. Large, yolky eggs present. Spermathecae absent.

Remarks. *Heronidrilus gravidus* is an assumed parthenogenetic species described from the Caribbean area in the Atlantic Ocean (Erséus 1990d). The present material is hard to distinguish from this form, due to the rudimentary nature of the genitalia; the somatic characters are not sufficient for the discrimination of specific taxa. However, the genus may include more than one form that has evolved parthenogenesis.

Distribition and habitat. Belize, ?Northern Territory (new record), if the present species indeed is *H. gravidus.* Intertidal and subtidal sand, to at least 7 m depth.

Genus *Heterodrilus* Pierantoni, 1902
Heterodrilus keenani Erséus, 1981

Heterodrilus keenani Erséus, 1981b: 117-118, fig. 7. - Erséus 1984b: 140-142, fig. 4; -Erséus 1990b: 48; - Erséus 1990c: 273; - Erséus and Davis 1989: 76, fig. 1C-E; - Erséus 1993: 339.

New material. NTM Wo 0009, specimen from Station 11.

Remarks. A single worm out of all individuals of *Heterodrilus* found in the present study was identified as *H. keenani*, a species widely distributed and probably common in the Indo-West Pacific region. It has rather short, C-shaped atria, and not the long, more or less M-shaped atria characteristic of *H. claviatriatus* (see below). Otherwise these two species are very similar. They have, for example, virtually identical setal patterns.

Distribution and habitat. Northern Territory (new record), Queensland, Western Australia, southern China, Hawaii. Intertidal and subtidal sands, to at least 70 m depth.

Heterodrilus claviatriatus Erséus, 1981

Heterodrilus claviatriatus Erséus, 1981b: 118-119, fig. 8. - Erséus 1993: 341-342, fig. 3.

New material. NTM Wo 0010-0012, 3 specimens from Station KAC-37. SMNH Main coll. 1419-1420, 2 specimens from Station 20. SMNH Main coll. 1421-1423, 3 specimens from Station 26. Author's collection: 1 sectioned (Station 11) and 5 whole-mounted specimens (1 from each of Stations 11 and 13, and 3 from Station KAC-35).

Remarks. *Heterodrilus claviatriatus* has been reported and described from the Great Barrier Reef as well as Western Australia (Erséus 1981b, 1993). For most characters, the new material overlaps dimensionally with what was given in the previous descriptions. The vasa deferentia of the worms from Darwin, however, appear to be somewhat wider (up to at least 18 µm) than noted before (maximally 12 µm), and in one specimen, the penial setae are up to 110 µm long (maximally 100 µm in previous material). Moreover, in the present material, the spermathecal pores are slightly dorsal to the lines of the ventral setae. They are thus somewhat closer to the lateral lines than those of the previously described worms.

Distribution and habitat. Northern Territory (new record), Queensland, Western Australia. Intertidal and subtidal sands, to at least 11 m depth.

Heterodrilus rapidensis sp. n.
(Fig. 1)

Type material. HOLOTYPE - NTM Wo 0013, sexually mature specimen, from Rapid Creek, Nightcliff (Station 16). PARATYPES - NTM Wo 0014, sexually immature specimen from type locality; SMNH Type coll. 4683, sexually immature specimen from Station 34.

Description (for most parts, referring to holotype only). Length 14.6 mm, with 88 segments; paratypes smaller (immature). Width at XI, 0.40 mm. Prostomium rounded triangular, but much shorter than wide. Clitellum extending over ½X-XII. Setae two per bundle in II-IX, one per "bundle" thereafter, but absent ventrally from XI (no penial setae present). Anterior setae (Fig. 1A) trifid, with middle tooth longer than other two, upper tooth thin and pointed, lower tooth short and broad. These setae 55-100 µm long, 3-5 µm thick. From XIII, XVI (paratypes) or XX (holotype) and backwards to XIX, XXV (paratypes) or XXVIII (holotype), both dorsal and ventral setae bifid (Fig. 1B), with both teeth basally wide, but upper tooth longer than lower. These setae up to 95 µm long, and up to 7 µm thick. Following these, ventral setae sharply single-pointed and stout (Fig. 1C), up to 135 µm long, 8 µm thick, while dorsal setae bifid (Fig. 1D) and much shorter (maximally about 60 % of length of corresponding ventral setae). Male pore unpaired, mid-ventral, in posterior part of XI. Spermathecal pore unpaired, mid-ventral, anteriorly in X.

Pharyngeal glands in IV-VI. Coelomocytes round, finely granulated, but few (not as numerous and conspicuous as in most other species of *Heterodrilus*). Male genitalia (Fig. 1E) paired, except for unpaired copulatory sac. Vas deferens not observed in its whole length, but part close to atrium (Fig. 1E: vd) 30-35 µm wide. Entrance of vas appearing subapical on atrium. Atrium (Fig. 1E: a) somewhat pear-shaped (with narrow end towards copulatory sac), bent, about 90-100 µm long, 60-70 µm wide, with thin, indistinct outer layer and somewhat granulated inner epithelium; latter appearing non-ciliated, but details not clear. Atrium with two distinct prostate glands (Fig. 1E: pr 1-2), attached to anterior and posterior side, respectively. Posterior prostate (pr 2) extending through most of XII. Two atria entering opposite lobes of bilobed, unpaired, copulatory sac (Fig. 1E: lcs). Latter bearing two pairs of small prostate-like glands. Lobes of sac joined together mid-ventrally, sac opening to exterior through slit-like (male) pore (Fig. 1E: mp). Spermatheca (Fig. 1E: s) unpaired, consisting of bulbous, thick-walled duct, 90 µm long, 55 µm wide, and somewhat oval, thin-walled, ampulla, about 175 µm long, 90 µm wide; latter containing large bundle of sperm.

Remarks. Only one sexually mature specimen (holotype) of this species is available. The paratypes, however, have a setal arrangement identical to that of the holotype, and there is no doubt that they all belong to the same species. It is possible that the unusual, anisomorphic setal pattern in the majority of the postclitellar segments (with large, single-pointed, ventral setae and much smaller, bifid, dorsal setae) is an adaptation to unstable sediments. The ventral setae may aid in the holding on to large sediment particles. Both Stations 16 and 34 are in tidal creeks with coarse sediments, and with swift currents at low tides.

Heterodrilus rapidensis is strikingly similar to *H. inermis* (Erséus, 1981b), with regard to the genital structures. However, whereas in *H. inermis* all setae from segments posterior to about XXX are sharply single-pointed and of the same size dorsally and ventrally, the new species has anisomorphic setae in the posterior part of the body, commencing at XXVI-XXIX (dorsal setae small and bifid, ventral ones large and single-pointed). In addition, the new taxon appears to have unusually wide vasa deferentia (up to 30-35 µm); the vasa of *H. inermis* are only up to 18 µm wide (Erséus 1981b).

Heterodrilus inermis and *H. ersei* (Giere, 1979) were earlier placed in a genus of their own, *Giereidrilus* Erséus, 1981(b), but according to Erséus (1990d), this taxon is merely an advanced group within *Heterodrilus* characterized by unpaired male and spermathecal pores (which is apomorphic vis-à-vis the paired genital pores of all congeners), and the two genera should be regarded as synonyms. *Heterodrilus rapidensis* and *H. apparatus* Erséus, 1993, from Western Australia, both belong to this group.

Distribution and habitat. Northern Territory. Intertidal coarse sand.

Etymology. Named for Rapid Creek, the type locality.

Genus *Ainudrilus* Finogenova, 1982
Ainudrilus mediocris sp. n.
(Fig. 2A-D)

Type material. HOLOTYPE - NTM Wo 0015, from Woods Inlet (Station BH-60). PARATYPES - NTM Wo 0016-0019, 4 specimens (1 sectioned) from type locality; SMNH Type coll. 4684-4688, 5 specimens from Station BH-53.

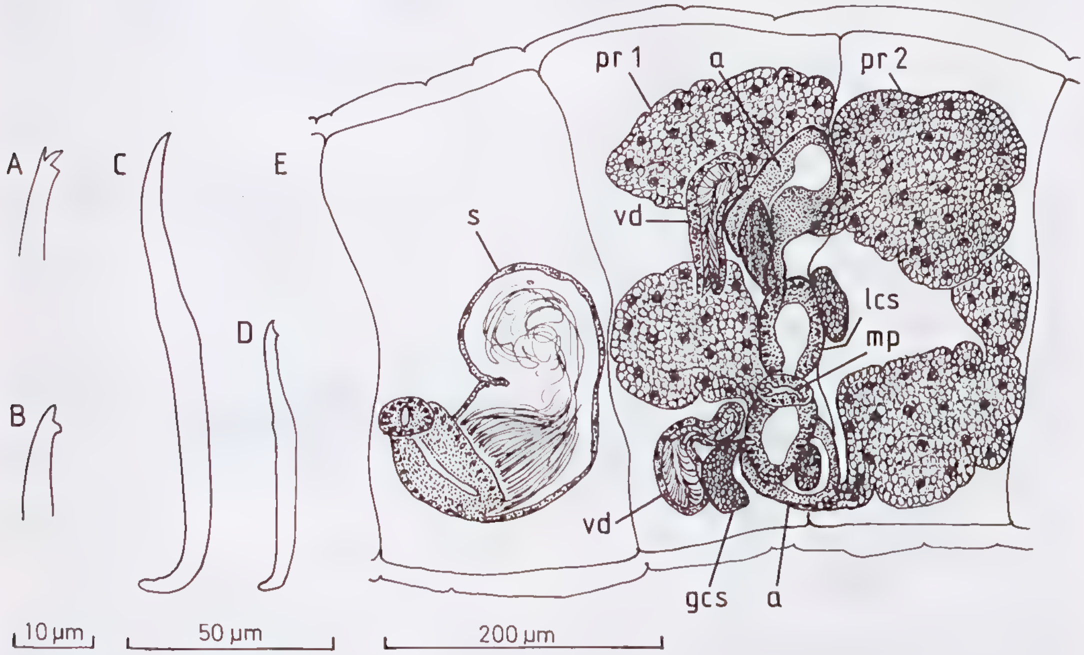

Fig. 1. *Heterodrilus rapidensis* sp. n. **A**, seta from IX; **B**, seta from XXII; **C-D**, ventral (**C**) and dorsal seta (**D**) from the same midbody segment; **E**, ventral view of spermatheca and male genitalia in X-XII (note that only parts of vasa deferentia are shown).

Other material examined (author's collection). Five specimens: 1 from each of Stations BH-47, BH-60 (type locality) and BH-69; and 2 from Station BH-51.

Description. Length 3.8-7.8 mm, 28-40 segments. Width at XI, 0.25-0.37 mm. Prostomium variable, generally pointed, triangular with somewhat rounded tip. Clitellum extending over ½X-XII. Somatic setae (Fig. 2A) bifid, with upper tooth much longer than lower. These setae 35-60 µm long, 2-2.5 µm thick, (1)2-4 per bundle throughout worm. Penial setae (Fig. 2B C: ps), generally one (occasionally two) at each side of worm, single-pointed, 42-60 µm long, 2.5-3.5 µm thick; in one specimen, one bifid (somatic) seta still present beside one of (modified) penial setae. Male pores paired, in line with ventral setae, posterior to middle of XI. Spermathecal pores paired, in line with ventral setae, in most anterior part of X.

Pharyngeal glands in (III)IV-VI. Gut distended, with wall thicker than elsewhere in X-XI. Coelomocytes abundant, globular, granulated. Male genitalia (Fig. 2C) paired; vasa deferentia not observed. Atrium (Fig. 2C: a) bipartite, club-shaped, erect or with inner end obliquely directed towards posterior. Atrial ampulla round or oval, about 45-70 µm long, 30-55 µm wide, with thin or moderately thick, non-muscular, wall, and containing bundle of sperm. Atrial duct 28-45 µm long, 8-20 µm wide, tapering, without muscular outer layer, opening to exterior through simple pore. Spermathecae (Fig. 2C: s; 2D) with conspicuous, slit-like vestibules (sv); ducts 20-35 µm long, 20-30 µm wide; ampullae thin-walled, pear-shaped or elongate, 40-100 µm long, 25-50 µm wide. Sperm as bundle or small random mass in each spermatheca.

Remarks. *Ainudrilus mediocris* is similar to the Caribbean *A. geminus* Erséus, 1990(d), which also has simple, club-shaped, more or less erect atria, and unisetal "bundles" of penial setae. The latter species, however, has ectally flattened penial setae and lacks spermathecae.

Distribution and habitat. Northern Territory. Intertidal, mostly in mangrove mud.

Etymology. Named *mediocris* (Latin for 'moderate'), referring to the low number of

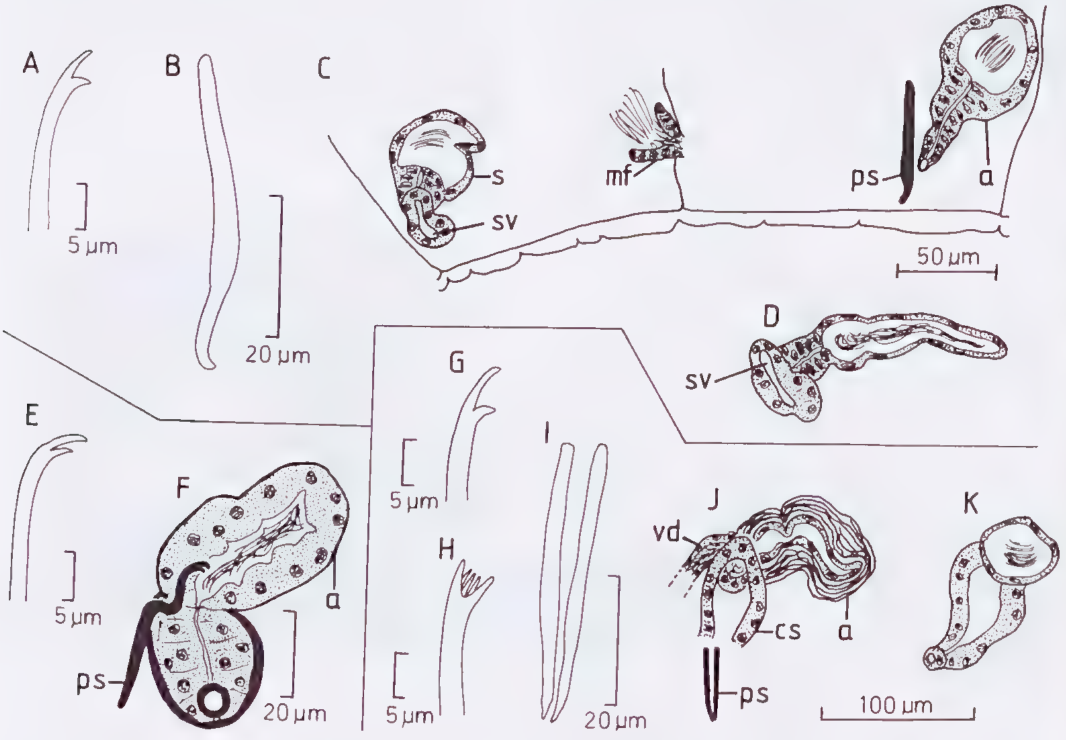

Fig. 2. A-D, *Ainudrilus mediocris* sp. n.; **A**, somatic seta; **B**, penial seta; **C**, lateral view of spermatheca and male genitalia in X-XI (holotype); **D**, spermatheca of another specimen (paratype); **E-F**, *Ainudrilus stagnalis* sp. n.; **E**, somatic seta; **F**, atrium and penial seta; **G-K**, *Ainudrilus brendae* sp. n.; **G**, ventral somatic seta; **H**, dorsal, pectinate seta; **I**, penial setae; **J**, male genitalia, also showing location of penial setae vis-à-vís male pore; **K**, spermatheca.

penial setae; this species has only one penial seta at each male pore, whereas most other species of *Ainudrilus* have two or more such setae per bundle.

Ainudrilus stagnalis sp. n.

(Fig. 2E-F)

Type material. HOLOTYPE - NTM Wo 0020, from billabong at Stephen's Creek (Station 42).

Description. Length 3.2 mm, with 20 (anterior) segments, but not complete. Width at XI, 0.31 mm. Prostomium short, rounded. Clitellum extending over ½X-XII. Somatic setae (Fig. 2E) bifid, with upper tooth much longer than lower. These setae 35-70 µm long, 1.5-2 µm thick, four to six per bundle anteriorly, three to four per bundle in postclitellar segments. Penial setae (Fig. 2F: ps), one at each side of worm, also bifid, about 60 µm long, 2.5 µm thick, somewhat twisted (probably artefact caused by mounting) These setae similar to, but little thicker than, somatic setae (see Remarks). Male pores paired, situated close to each other ventrally, i.e., clearly ventral to lines of ventral setae, posterior to middle of XI. Spermathecal pores absent.

Pharyngeal glands in III-VI. Gut distended, with wall thicker than elsewhere in X-XI. Coelomocytes abundant, globular, granulated. Male genitalia paired; but vasa deferentia not observed. Atrium (Fig. 2F: a) bipartite, somewhat club-shaped, with apical (inner) end directed towards posterior. Atrial ampulla about 50 µm long, about 25 µm wide, with thick, but non-muscular wall, and containing bundle of sperm. Atrial duct about 35 µm long, 27 µm wide, with thick muscular outer layer. Duct opening to exterior through simple pore. Spermathecae absent.

Remarks. Although the present specimen appears to have reached full sexual maturity, the (single) bifid setae at the male pores are similar to the ordinary somatic setae, and possibly will be replaced by more modified penial setae at a later stage. Such a replacement of setae at the male pores was reported for *A. geminus* (see Erséus 1990d).

Ainudrilus stagnalis is the only taxon reported from freshwater in the present study. The only other known freshwater species of *Ainudrilus* is *A. billabongus* (Brinkhurst, 1984), also described from the Northern Territory. It differs from the new species in several respects: (1) the teeth of its setae are almost equally long (upper teeth much longer than lower in *A. stagnalis*); (2) it has numerous, single-pointed, penial setae, although the morphology and number of penial setae in fully mature *A. stagnalis* may still be unknown (see above); (3) its atria are heavily muscular throughout, whereas the atrial ampullae of *A. stagnalis* lack muscles; and (4) its possession of spermathecae.

With regard to its (apomorphic) lack of spermathecae, *A. stagnalis* resembles *A. geminus* (see Remarks for *A. mediocris* above), but the two taxa are easily separated by the morphology of the atrial ducts; those of *A. stagnalis* are bulbous and muscular (Fig. 2F), those of *A. geminus* (and *A. mediocris*) are more slender, tapering and non-muscular.

In the present material of *Ainudrilus*, the single specimen of *A. stagnalis* was immediately recognized as different from the many specimens of *A. mediocris*. Its somatic setae are more slender and more numerous than those of the latter (up to six per bundle anteriorly, as opposed to maximally four per bundle in *A. mediocris*).

Distribution and habitat. Northern Territory. Freshwater, in fine sand.

Etymology. Named *stagnalis* for its occurrence in a freshwater pool (*stagnum* is Latin for 'pond, pool').

Ainudrilus brendae sp. n.

(Fig. 2G-K)

Type material. HOLOTYPE - NTM Wo 0021, from Sadgroves Creek (Station BH-51).

Description. Length 5.0 mm, with 46 segments. Width at XI, 0.46 mm. Prostomium short, rounded triangular. Clitellum extending over 1/2X-XII. Ventral somatic setae (Fig. 2G) all bifid, with upper tooth much longer than lower, four to five per bundle anteriorly, two to four per bundle in postclitellar segments. Bifid setae 40-65 µm long, 1.5-3 µm thick. Anterior dorsal bundles with (1)2 hair setae, up to about 140 µm long, and two to three pectinate setae. Posterior to clitellum, dorsal bundles with 0-2 short hairs and 2-3 pectinates. Pectinate setae (Fig. 2H) 50-60 µm long, 2-2.5 µm thick, generally with marginal teeth similar and somewhat parallel, intermediate teeth few and indistinct (occasionally absent?); upper marginal tooth lost(?) in some pectinates of posterior segments. Penial setae (Fig. 2I; J: ps) single-pointed, almost straight, about 50 µm long, 2.5 µm thick, two per bundle. Bundles of penial setae located somewhat ventral to male pores (Fig. 2J), pointing toward mid-ventral line of worm and thus dislocated from line of other ventral setae. Male pores paired, in line with ventral (somatic) setae, in about middle of XI. Spermathecal pores paired in line with ventral setae, anteriorly in X.

Pharyngeal glands in III-VII. Gut appearing somewhat distended, and more thick-walled than elsewhere in clitellar region (this not as clear as in material of other species of *Ainudrilus* studied by author). Coelomocytes abundant, spherical, granulated. Male genitalia (Fig. 2J) paired. Vas deferens about 15 µm wide, appearing to enter base (ectal end) of atrium, but not observed throughout its length. Atrium (Fig. 2J: a) elongate, with inner end oriented towards posterior and reaching septum XI/XII. Atrial ampulla about 140 µm long, about 45-55 µm wide, with thick, but loose (?; may be due to poor fixation) layer of muscle fibers, lumen of ampulla wide, appearing non-ciliated. Ampulla opening into copulatory sac (Fig. 2J: cs), about 70 µm long, about 40 µm wide; sac probably acting as eversible pseudopenis, details not clear. Prostate glands absent. Spermathecae (Fig. 2K) consisting of conspicuous, thick-walled ducts, about 75 µm long, 55 µm wide, and small, roundish, thin-walled ampullae; latter containing random sperm.

Remarks. This new species appears closely related to *A. taitamensis* Erséus, 1990(c) from Hong Kong, although it has much shorter atrial ampullae (those of *A. taitamensis* are up to 500 µm long and extend backwards into XII or XIII). Another striking difference is that *A. brendae* only has two small (single-pointed) setae in each penial bundle, whereas the penial setae of *A. taitamensis* are larger, three to six per bundle, and clearly bifid with unusually large upper teeth.

See also Remarks for *A. piliferus* sp. n. described below.

Distribution and habitat. Northern Territory. Intertidal mangrove mud.

Etymology. Named for Dr Brenda Healy (Dublin, Ireland), who collected the type material, and who supplied many valuable samples during the workshop in Darwin.

Ainudrilus piliferus sp. n.
(Fig. 3)

Type material. HOLOTYPE - NTM Wo 0022, from Sadgroves Creek (Station BH-51).

Description. Single specimen damaged and unnaturally elongated; it may have been moribund at time of fixation. Length 6.1 mm, with 41 segments. Width at XI, 0.24 mm. Prostomium elongate, with rounded tip (but appears distorted). Clitellum extending over 1/2X-XII. Ventral setae (Fig. 3A) bifid, with upper tooth

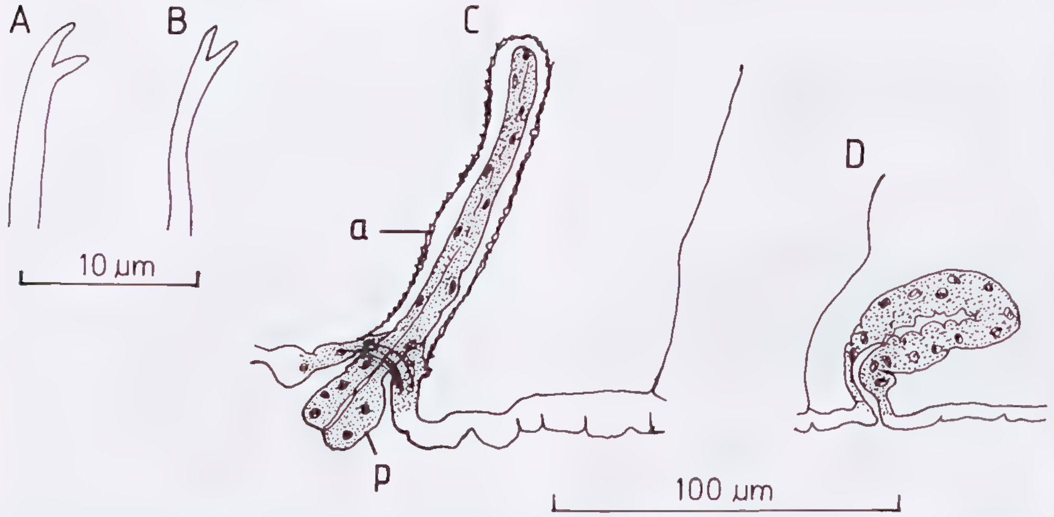

Fig. 3. *Ainudrilus piliferus* sp. n.; **A**, ventral seta; **B**, dorsal, bifid seta; **C**, lateral view of atrium and penis in posterior part of XI; **D**, lateral view of spermatheca in anterior part of X.

longer than lower, two to four per bundle anteriorly, two per bundle in postclitellar segments. Ventral setae 45-55 µm long, 2-2.5 µm thick. Dorsal bundles with none or one hair seta, and two or (posteriorly often) only one bifid (possibly pectinate?) seta. Hairs thin, up to at least about 300 µm long, generally twisted. Dorsal bifid/pectinate? setae (Fig. 3B) 45-55 µm long, 2-2.5 µm thick, with marginal teeth similar and somewhat parallel; intermediate teeth, if present at all, few and indistinct. Penial setae absent. Male pores paired, in line with ventral setae, in about middle of XI. Spermathecal pores paired, in line with ventral setae, anteriorly in X.

Pharyngeal glands in III-VII. Gut somewhat distended, and more thick-walled than elsewhere, at least in X (view obscured by clitellum). Coelomocytes spherical, granulated, but not abundant. Male genitalia (Fig. 3C) paired; vasa deferentia, however, not observed. Atrium (Fig. 3C: a) cylindrical, slender, 90-105 µm long, about 20 µm wide, consisting of inner core of epithelial cells, and thin, detached, outer muscular layer. Inner end of atrium obliquely pointing towards posterior. Lumen of atrium closed (atrial tissue appears shrunken); thus presence/absence of ciliation not known. Atria terminating in club-shaped copulatory organs (Fig. 3C: p), appearing pendent, proper penes, protruded at both sides in holotype. Spermathecae (Fig. 3D: s) oval, 65-70 µm long, 21-28 µm wide, but not fully developed and thus devoid of sperm.

Remarks. Although certain features of this specimen are still not properly described, it is obvious that it represents a new species of Rhyacodrilinae. Similarities with *A. taitamensis* Erséus, 1990(c), and *A. brendae* sp. n., in the morphology and arrangement of somatic setae, and the general form and orientation of the atria, suggest that it belongs to *Ainudrilus*. However, it (1) lacks penial setae (penial setae present in *A. taitamensis* and *A. brendae* sp. n.), but (2) has distinct, penis-like organs (atria opening through simple pores in the other two species). Moreover, (3) its atria are smaller and simpler than those of *A. taitamensis* and *A. brendae* sp. n.

Distribution and habitat. Northern Territory. Intertidal mangrove mud.

Etymology. Named *piliferus* (Latin for 'bearing a hair'), referring to the single, very long, hair seta in some dorsal bundles.

Genus *Paupidrilus* Erséus, 1990
Paupidrilus breviductus Erséus, 1990

Paupidrilus breviductus Erséus, 1990c: 270-271, fig. 3.

New material. NTM Wo 0023, specimen from Station BH-60. NTM Wo 0024-0025, 2 specimens from Station BH-61. SMNH Main coll. 1424-1425, 2 specimens from Station 27. SMNH Main coll. 1426, specimen from Station BH-57.

Remarks. This small tubificid was previously known only from Hong Kong (Erséus 1990c). Its male ducts are inconspicuous, with small, erect, atria and simple external pores, and they lack prostate glands. The spermathecae are also small, opening to the exterior (via small vestibules) in the most posterior part of IX, instead of in X, which is normal for a tubificid.

Three of the new specimens are complete. They are 2.1-3.9 mm long, with 25-35 segments, which extends the known size range of the species; the worms of the original material were 2.1-2.8 mm long, with 28-34 segments. The atria of the Darwin individuals are wider (up to about 25 µm) than those of the worms from Hong Kong (maximally 12 µm wide), but in all other respects the present material conforms with the original description.

A few round coelomocytes are present in some of the new specimens; *P. breviductus* has less abundant coelomocytes than most other rhyacodrilines (Erséus 1990c).

Distribution and habitat. Northern Territory (new record), southern China. Intertidal sand and gravel; in present study also in mangrove mud.

Genus *Albanidrilus* Erséus, 1992
Albanidrilus wellsi (Erséus, 1990)

Phallodrilus wellsi Erséus, 1990b: 57-59, fig. 6.

Albanidrilus wellsi - Erséus 1992a: 17-18, fig. 6F. - Erséus 1993: 345-346, fig. 6.

New material. NTM Wo 0026-0029, 4 specimens from Station 25. SMNH Main coll. 1427-1430, 4 specimens from Station 22.

Remarks. *Albanidrilus wellsi* was previously known only from Western Australia; it was particularly common at Rottnest Island (Erséus 1990b, 1993). In the present study, it was found only at two stations at West Point (Cox Peninsula).

The new specimens are somewhat smaller than those from Rottnest Island; two complete individuals from Station 22 are 3.4 and 3.7 mm long, with 38 and 41 segments, respectively (in Rottnest material, 3.9-7.6 mm, 40-53 segments). In the new worms, the penial setae are 80-90 µm long (in Rottnest material, up to 115 µm), and the atria are 65-90 µm long (in Rottnest material, up to 120 µm). However, a more noteworthy difference is that, while the spermathecal pores were located "just ventral to lateral lines" (Erséus 1993) in the material from Western Australia, they are in line with the ventral setae in the worms from the Northern Territory. This difference probably reflects the great geographic distance between the two populations.

In some of the Darwin specimens, the spermathecal ampullae contain many secretory granules. These ampullae are considerably larger than the one of a Rottnest Island individual illustrated by Erséus (1993: fig. 6).

Distribution and habitat. Northern Territory (new record), Western Australia. Intertidal or subtidal, often coarse, sediments, to at least 11 m depth.

Albanidrilus coxensis sp. n.
(Fig. 4)

Type material. HOLOTYPE - NTM Wo 0030, from Woods Inlet (Station 34).

Description. Length more than 5.7 mm, with more than 39 segments (holotype not complete). Width at XI, 0.22 mm. Prostomium rounded triangular, about as long as wide. Clitellum not developed. Somatic setae (Fig. 4A) bifid, with upper tooth thinner and shorter than lower, and with subdental ligament. Bifid setae 38-48 µm long, 2-3 µm thick, 2-4 per bundle anteriorly, 2(3) per bundle in postclitellar segments. Penial setae (Fig. 4B, C: ps) not fully developed, but two per bundle, single-pointed, and morphologically different within bundle. At one side of worm, (1) one penial seta about 60 µm long, with setal shaft about 7.5 µm thick (or wide; shaft possibly flat), and with ectal part much narrower, and smoothly curved (tip perpendicular to axis of shaft), and (2) another penial seta (probably less developed than first penial seta) with shaft very short, about 7 µm wide, and with ectal end less strongly bent than that of first seta. At other side of worm, penial setae similar to these ((1)-(2)), but they are even shorter. Male pores paired, in line with ventral somatic setae, posteriorly in XI. Spermathecal pores immediately ventral to lateral lines, in most anterior part of X.

Pharyngeal glands in III-V. Male genitalia (Fig. 4C) paired. Vas deferens (Fig. 4C: vd) about 10 µm wide, without outer muscular layer, longer than atrium; entrance of vas into atrium not observed. Atrium (Fig. 4C: a) about 100 µm long, about 50 µm wide (very approximate measurements), somewhat sigmoid, bipartite (with two bulky parts). Outer layer of atrium indistinct (muscles not developed); exact histology

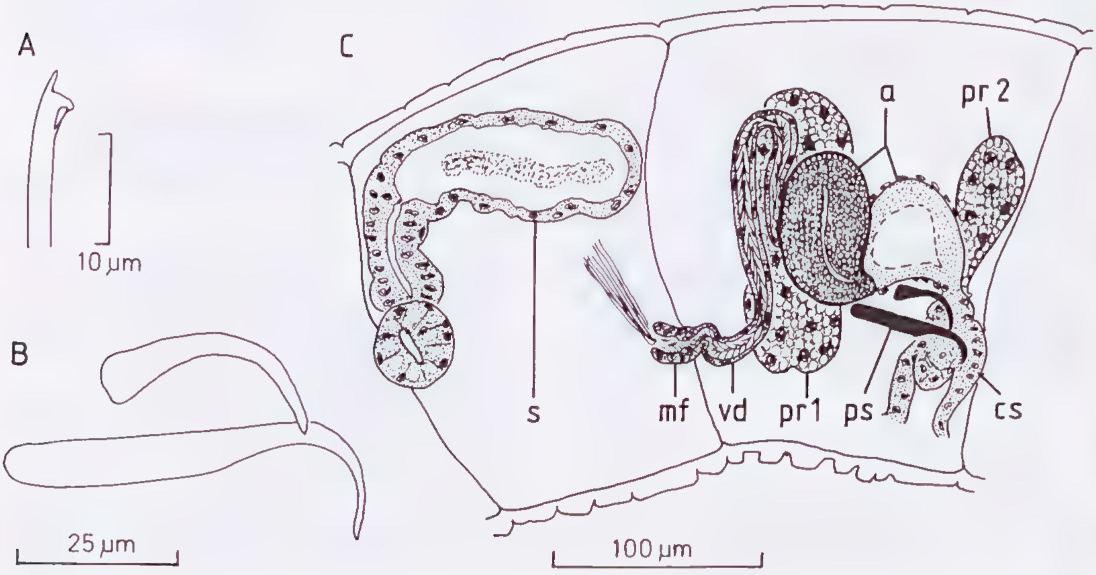

Fig. 4. *Albanidrilus coxensis* sp. n.; **A**, somatic seta; **B**, penial setae; **C**, lateral view of spermatheca and male genitalia in X-XI.

of inner epithelium not established, but ental part of atrium more granulated than ectal part. Atrium terminating in short, narrow duct leading to small copulatory sac (Fig. 4C: cs), but details not clear. Anterior prostate gland (Fig. 4C: pr 1) large, intermingled with vas deferens; attachment to atrium not seen. Posterior prostate gland (pr 2) smaller, located posterior to atrium; attachment not seen. Spermathecae (Fig. 4C: s) with indistinct vestibules; thick-walled ducts, about 65 µm long, about 30 µm wide; and elongate, thin-walled ampullae, about 125 µm long, about 45 µm wide. Specimen precopulatory; each spermathecal ampulla containing loose, amorphous, mass of unknown substance in middle, but sperm absent.

Remarks. Although the single available specimen is precopulatory and probably has not reached full sexual maturity, it is characteristic and different enough from all other species of *Albanidrilus*. The only other species with bisetal penial bundles is *A. wellsi*, but the penial setae of *A. coxensis* are horizontally oriented in the segment and have curved tips, whereas those of *A. wellsi* are straight.

There is a possibility that fully mature specimens of *A. coxensis* have more than two penial setae per bundle, in which case the new species would resemble *A. magnificus* Erséus, 1993, from Western Australia. The latter taxon also has horizontal penial setae, and its atria are similar to those of *A. coxensis*. Nonetheless, the morphology of the penial setae differs in the two species. In *A. magnificus*, the tip of the first (largest) penial seta in the bundle is less curved than in *A. coxensis*, and there is no great difference in thickness between the setal shafts and the tips as in the latter species.

Distribution and habitat. Northern Territory. Intertidal coarse sediment.

Etymology. Named for Cox Peninsula.

Albanidrilus caswellae sp. n.
(Fig. 5)

Type material. HOLOTYPE - NTM Wo 0031, from Woods Inlet (Station 6). PARATYPES - NTM Wo 0032, specimen from Station 16; SMNH Type coll. 4689, specimen from type locality.

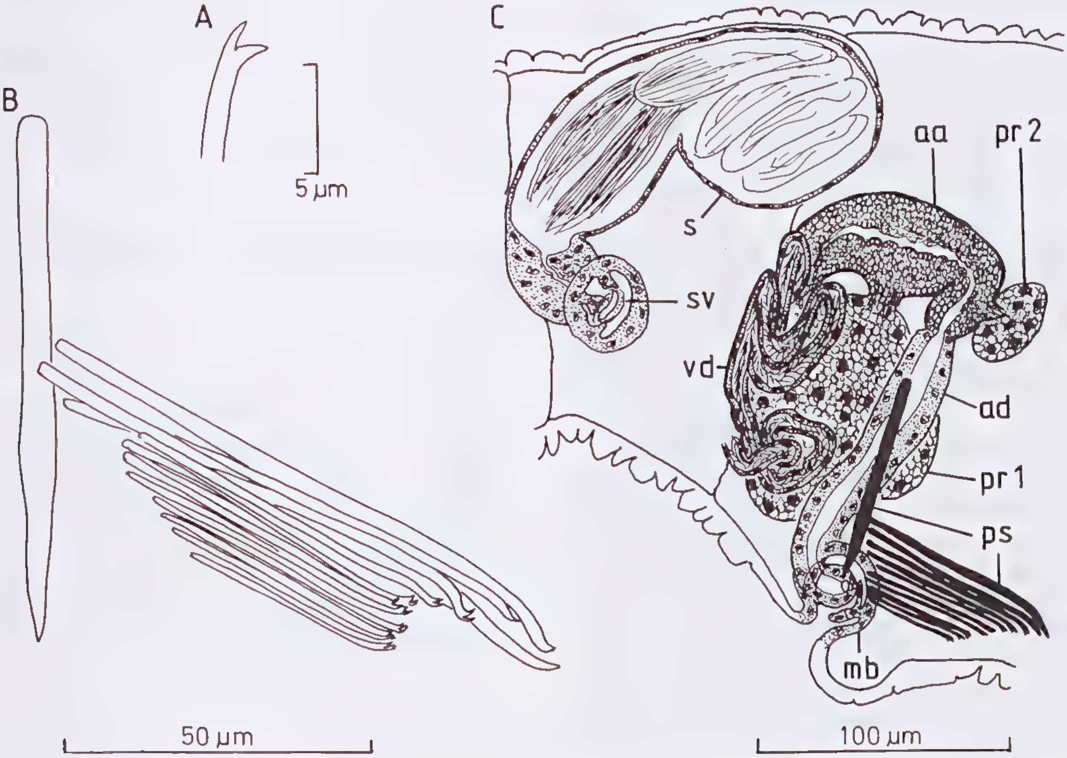

Fig. 5. *Albanidrilus caswellae* sp. n.; **A**, somatic seta; **B**, penial setae; **C**, lateral view of spermatheca and male genitalia in X-XI.

Description. Length (three specimens) 2.3-3.5 mm, about 30-38 segments (exact numbers difficult to establish). Width at XI, 0.20-0.36 mm, but specimens much compressed (widest one somewhat squashed). Prostomium small, slightly shorter than wide. Clitellum extending over ½X-XII. Somatic setae (Fig. 5A) bifid, with upper tooth slightly thinner and shorter than lower. Bifid setae 25-38 µm long, 1-1.5 µm thick, (1,2)3-5(6) per bundle anteriorly, (1)2-3 per bundle in postclitellar segments. Penial setae (Fig. 5B, C: ps) complex, each bundle containing one giant seta, perpendicular to long axis of worm, and 11-14 other setae of varying length, located close together, and with tips oriented more or less obliquely towards posterior. Giant penial seta solid, 85-90 µm long, 5-6 µm thick, sharply single-pointed and with straight tip. Other penial setae 35-100 µm long, 1.5-4 µm thick, gradually changing from single-pointed (longer setae) to bifid (shorter setae), and with tips somewhat curved. Male pores paired, but located in lateral walls of unpaired, large and somewhat convoluted, male bursa, mid-ventrally in middle of XI. Spermathecal pores paired, located between lateral line and line of ventral setae on each side of worm, in most anterior part of X.

Pharyngeal glands in III (and IV?), poorly developed. Male genitalia (Fig. 5C) paired, except for unpaired male bursa. Vas deferens (Fig. 5C: vd) 6-10 µm wide, much longer than atrium, convoluted, with very thin (but for most parts discernible) outer muscular layer; vas entering apical end of atrium. Atrium cylindrical, about 250 µm long, maximally (i.e. at ampulla) 25-38 µm wide, consisting of curved ental ampulla (Fig. 5C: aa) and slender ectal duct (ad). Ampulla with thin outer muscular layer, and granulated inner epithelium (ciliation of latter, however, not observed); duct not granulated. Atrial ampulla bearing two pedunculate prostate glands; anterior one (Fig. 5C: pr 1) attached to concave face of ampulla at some distance from entrance of vas deferens, posterior one (pr 2) attached to convex face of ampulla, but closer to beginning of atrial duct. Atrial ducts of both sides open, as simple pores, into lateral, somewhat folded, walls of male bursa (Fig. 5C: mb). Spermathecae (Fig. 5C: s) consisting of three parts: indistinct, probably somewhat lobed (details unclear) vestibules (Fig. 5C: sv); thick-walled ducts, about 60-70 µm long, 28-33 µm wide; and large, thin-walled ampullae, about 175-190 µm long, 50-85 µm wide. Spermathecal ampullae containing characteristic, slender spermatozeugmata (Fig. 5C: sz); each spermatozeugma a hyaline flask-to-club-shaped capsule surrounding a bundle of closely packed spermatozoa.

Remarks. *Albanidrilus caswellae* is closely related to *A. magnificus* Erséus, 1993, from Western Australia. Both species have complex bundles of penial setae and flask-to-club-shaped spermatozeugmata, both likely to be apomorphic features. The new species differs, however, from *A. magnificus* by its (1) greater number of, and more diversified, penial setae (in *A. magnificus*, each bundle contains one "giant" seta plus only 6-7 smaller ones, and the largest seta is not dislocated from the others; compare Fig. 5B; and Erséus 1993: fig. 7), (2) longer and more slender atria (atria of *A. magnificus* 110-125 µm long, 50-70 µm wide, and lacking duct-like ectal portions), and (3) possession of an unpaired male bursa (*A. magnificus* has paired copulatory sacs). Moreover, in *A. magnificus* the spermathecal vestibules are voluminous and granulated (Erséus 1993: fig. 7D); those of *A. caswellae* appear less developed (Fig. 5C: sv).

Distribution and habitat. Northern Territory. Intertidal, coarse sediment.

Etymology. Named for Ms Gabi Caswell (Darwin, Northern Territory, Australia), for all her invaluable assistance in the preparation and realization of the Mandorah workshop.

Genus *Jamiesoniella* Erséus, 1981

Jamiesoniella athecata Erséus, 1981

Jamiesoniella athecata Erséus, 1981a: 28-29, figs 27-29. - Erséus 1990d: 265-266, fig. 17; - Erséus 1992b: 168-169, fig. 7.

New material. NTM Wo 0033 and SMNH Main coll. 1431, 2 specimens from Station 27.

Remarks. *Jamiesoniella athecata* is a meiobenthic, intertidal species, described from as separate areas as the Great Barrier Reef (Erséus 1981a), Hong Kong (Erséus 1992b), and Belize, Atlantic coast of Central America (Erséus 1990d). The new material conforms with the previous descriptions.

Distribution and habitat. Northern Territory (new record), Queensland, southern China, Belize. Intertidal, largely coarse sand.

Genus *Pectinodrilus* Erséus, 1992
Pectinodrilus heronensis (Erséus, 1981)

Phallodrilus rectisetosus heronensis Erséus, 1981a: 15-17, figs 1-3, table I.

Phallodrilus heronensis - Erséus 1988: 789-790, fig. 3.

Pectinodrilus heronensis - Erséus 1992a: 36.

New material. NTM Wo 0034, specimen from Station 1. NTM Wo 0035, specimen from Station 33. SMNH Main coll. 1432-1433, 2 specimens from Station BH-69.

Brief description of new material. Length (three complete specimens) 3.3-4.5 mm, 33-37 segments. Somatic setae two to three per bundle anteriorly, two per bundle in postclitellar segments. Penial setae (5)6 per bundle, 25-30 µm long. Atria small, spindle-shaped, 35-45 µm long. Spermathecae slender, club-shaped, 65-90 µm long, 20-28 µm wide; ampullae small, containing some scattered spermatozoa.

Remarks. This species and *P. molestus* (see below) belong to a complex of small, very similar species within *Pectinodrilus*, the "*P. rectisetosus* complex" (Erséus 1988, 1992a). *Pectinodrilus heronensis*, which was first described from the Great Barrier Reef, is distinguished from the other taxa in this complex by its small, club-shaped, spermathecae; the other species have large, more or less pear-shaped spermathecal ampullae. Previously, *P. heronensis* was also believed to have consistently smaller atria than the others (Erséus 1988), but considerable overlap in atrial size subsequently has been reported for *P. heronensis* and *P. molestus* (Erséus 1992b).

Distribution and habitat. Northern Territory (new record), Queensland, Fiji, Aldabra (Indian Ocean). Intertidal and barely subtidal sands.

Pectinodrilus molestus (Erséus, 1988)

Phallodrilus rectisetosus deminutius (*partim*) - Erséus 1979b: 191-192. - Erséus 1981a: table I.

Phallodrilus molestus Erséus, 1988: 787-789, figs 1B-D, 2D-F; - Erséus 1990d: 261.

Pectinodrilus molestus - Erséus 1992a: 36; - Erséus 1992b: 162-163, fig. 3.

New material. NTM Wo 0036, specimen from Station BH-69.

Brief description of new material. Length 3.3 mm, 31 segments. Somatic setae two (very seldom one) per bundle. Penial setae three per bundle, about 30 µm long. Atria not visible. Spermathecae consisting of narrow ducts, about 25 µm long, and oval ampullae, 55-70 µm long, 30-35 µm wide; each ampulla with loose sperm bundle inside.

Remarks. *Pectinodrilus molestus* is readily distinguished from *P. heronensis* by its lower number of anterior somatic, and penial, setae, and its larger spermathecal ampullae. The single specimen of *P. molestus* co-occurred with *P. heronensis* at Station BH-69.

Distribution and habitat. Northern Territory (new record), Queensland, Fiji, Hawaii, southern China, Florida, Belize, Barbados. Intertidal and subtidal sands, to at least 70 m depth.

Pectinodrilus multiplex (Erséus, 1990)

Phallodrilus multiplex Erséus, 1990b: 60-62, fig. 8.

Pectinodrilus multiplex - Erséus 1992a: 36, fig. 19G; - Erséus 1993: 352-353, fig. 9.

New material. NTM Wo 0037 and SMNH Main coll. 1434, 2 specimens from Station 41.

Remarks. *Pectinodrilus multiplex* was previously known only from Western Australia (Erséus 1990b, 1993). It has complicated male ducts which originally were in part erronously described (see Erséus 1992a), and a mid-dorsal (unpaired) spermatheca. The new specimens, both 5.6 mm long, with 54 and 48 segments, respectively, conform well with the previous material. For instance, their penial setae are 50-60 µm long, six to seven per bundle, which are within the ranges noted for the Western Australian material.

Distribution and habitat. Northern Territory (new record), Western Australia. Intertidal and subtidal sands, to at least 1.5 m depth.

Genus *Pacifidrilus* Erséus, 1992
Pacifidrilus aquilinus (Erséus and Davis, 1989)

Phallodrilus aquilinus Erséus and Davis, 1989: 80-81, fig. 4.

Pacifidrilus aquilinus - Erséus 1992a: 37.

New material. NTM Wo 0038-0040, 3 specimens from Station 14. SMNH Main coll. 1435-1436, 2 specimens from Station 6. SMNH Main coll. 1437, sectioned specimen from Station 14. SMNH Main coll. 1438-1441, 4 specimens from Station 11. Author's collection, 8 specimens: 1 from each of Stations 4, 10, 39, KAC-19, KAC-36 and KAC-37, and 2 from Station 34.

Remarks. This species was originally described from the Great Barrier Reef and Hawaii, as a species within *Phallodrilus* Pierantoni, but was later transferred to *Pacifidrilus* in a revision of that genus (Erséus 1992a). In the original material, one specimen from Hawaii was 10.4 mm long, with about 70 segments, whereas none of the Great Barrier Reef worms was complete. Ten complete individuals from the Darwin area are 3.8-7.1 mm long, with 41-54 segments.

The penial setae of the new specimens are bifid with slender, equally long and characteristically bent teeth (see Erséus and Davis 1989: fig. 4B-C). These setae are 40-50 µm long, (4)5-9 per bundle. The atria are spindle-shaped, with wide and conspicuously ciliated lumina. This conforms well with the type material from the Great Barrier Reef. The (large) worm from Hawaii had longer (up to 75 µm) and more numerous (14-18 per bundle) penial setae (Erséus and Davis 1989).

Distribution and habitat. Northern Territory (new record), Queensland, Hawaii. Intertidal and subtidal, largely coarse sediments, to at least 8 m depth.

Genus *Coralliodrilus* Erséus, 1979

Coralliodrilus improvisus sp. n.

(Fig. 6)

Type material. HOLOTYPE - NTM Wo 0041, from about 1 km S of Mandorah, Cox Peninsula (Station 40). PARATYPES - NTM Wo 0042, specimen from type locality; and SMNH Type coll. 4690, specimen from Station 41.

Description. Paratype from type locality complete, 3.0 mm long, with 46 segments; other specimens not complete. Width at XI, 0.18-0.23 mm. Prostomium rounded or somewhat triangular, at most about as long as wide. Clitellum extending over ½X-XII in holotype, poorly developed in paratypes. Somatic setae (Fig. 6A) bifid, with upper tooth much thinner, and slightly shorter than lower, and with subdental ligament. These setae 25-45 µm long, 1-2 µm thick, (2)3-4 per bundle anteriorly, (1)2-3 per bundle in postclitellar segments. Penial setae (Fig. 6B; C: ps) somewhat sigmoid, ectally fringed; i.e., tips blunt-ended (or hollow?), with pectinations in a more or less circular formation around margin. Penial setae 30-42 µm long, about 2.5 µm thick at middle, three per bundle. Male pores paired, in line with somatic setae, posteriorly in XI. Spermathecal pores paired, in lateral lines, in most anterior part of X.

Pharyngeal glands in IV-V(VI), poorly developed. Male genitalia (Fig. 6C) paired. Vas deferens (Fig. 6C: vd) about 7 µm wide, coiled and short, appears shorter than atrium, entering apical end of latter. Atrium bipartite, ental part a spindle-shaped, and somewhat curved or sigmoid ampulla (Fig. 6C: aa), 130-150 µm long, 45-65 µm wide, with 2-3.5 µm thick outer layer of spirally arranged muscles, and thick, granulated, ciliated inner epithelium. Ectal part

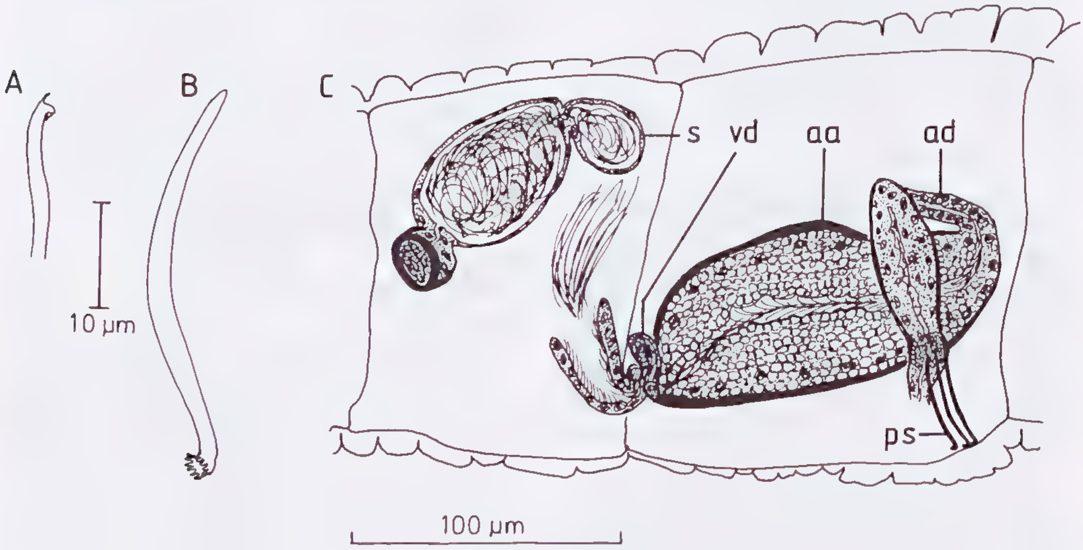

Fig. 6. *Coralliodrilus improvisus* sp. n.; **A**, somatic seta; **B**, penial seta; **C**, lateral view of spermatheca and male genitalia in X-XI.

of atrium a slender duct (Fig. 6C: ad), about 120 µm long, first narrow, but ending as elongate swelling, 22-28 µm wide, and opening to exterior through simple pore; swelling with thin, but distinct muscular layer. Prostate glands absent. Spermathecae (Fig. 6C: s) with short, somewhat muscular ducts, and thin-walled, bipartite ampullae, 95-120 µm long; inner (smaller) part of ampulla 25-30 µm wide, outer (larger) part up to about 50 µm wide. Sperm as random masses in spermathecal ampullae.

Remarks. Four species of *Coralliodrilus* have (1) variable, but more or less bipartite, spermathecal ampullae, as well as (2) distinctly bipartite atria, generally with ectal swellings on the atrial ducts (both characters likely to be synapomorphies): These are *C. aequalis* Erséus and Davis, 1989 (Hawaii), *C. angustiductus* Erséus, 1993 (Western Australia), *C. bidentatus* Erséus, 1993 (Western Australia and Queensland), and *C. improvisus* sp. n. *Coralliodrilus aequalis* lacks, whereas the other three species possess, penial setae. The new species is separated from *C. angustiductus* which has single-pointed penial setae, and *C. bidentatus* with bifid penial setae, as well as from all other members of the genus, by the unique, fringed tips of its penial setae (Fig. 6B).

Distribution and habitat. Northern Territory. Intertidal gravelly sand.

Etymology. Named *improvisus* (Latin for 'unexpected'), here referring to the strange and unique appearance of the tips of the penial setae.

Coralliodrilus hanleyi sp. n.

(Fig. 7)

Type material. HOLOTYPE - NTM Wo 0043, from East Arm (Station 10). PARATYPE - SMNH Type coll. 4691, from type locality.

Description. No complete specimen available; holotype 1.8 mm long, consisting of 28 anterior segments; paratype even smaller, consisting of segments VIII-XXIII only. Width at XI, 0.18-0.22 mm. Prostomium (holotype) shorter than wide. Clitellum well developed in both specimens, extending over posterior 1/3 of X, whole XI, and anterior 2/3 of XII. Somatic setae (Fig. 7A) bifid, with upper tooth slightly thinner than, but about as long as, lower. These setae 32-40 µm long, 1-1.5 µm thick, 3-4 per bundle anteriorly, 2-3 per bundle in postclitellar segments. One small penial seta (Fig. 7B; C: ps) at each male pore; these setae 23-30 µm long, entally 1-1.5 µm thick, ectally thinner, tips bifid with widely diverging teeth. Male pores paired, in line with ventral setae, posterior to middle of XI. Spermathecal pores paired, in line with ventral setae, in most anterior part of X.

Pharyngeal glands (holotype) in IV-VI. Male ducts (Fig. 7C) paired. Vas deferens (Fig. 7C: vd) 3.5-5 µm wide, coiled but shorter than atrium, entering apical end of latter. Atrium (Fig. 7C: a) bipartite, ental part an inconspicuous (poorly developed) ampulla, about 35 µm long, about 9 µm wide, with very thin, non-muscular, outer layer and virtually without

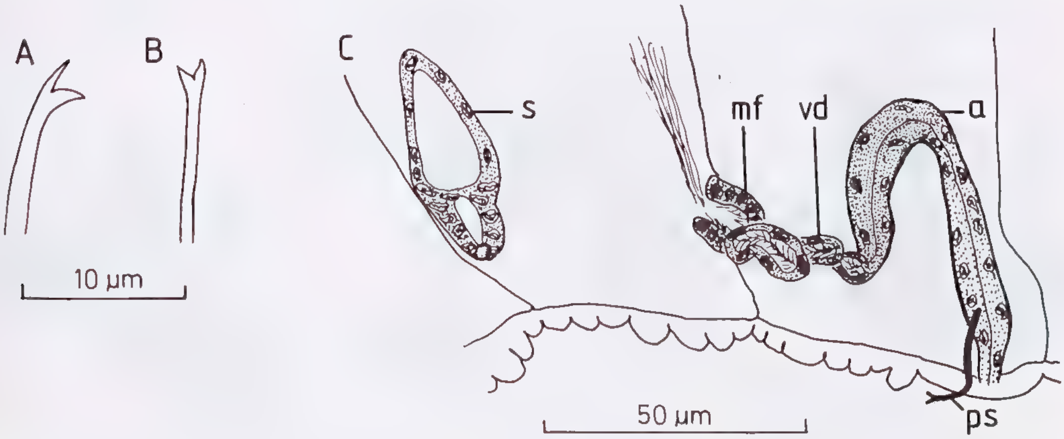

Fig. 7. *Coralliodrilus hanleyi* sp. n.; **A**, somatic seta; **B**, penial seta; **C**, lateral view of spermatheca and male genitalia in X-XI.

granulation in inner epithelium. Ectal part of atrium a slender duct, about 60 µm long, 5-7 µm wide, opening to exterior through simple pore. Prostate glands absent. Spermathecae (Fig. 7C: s) small (rudimentary?), with duct 12-15 µm long, 10-12 µm wide, and ampulla about 25 µm long, about 15 µm wide. Large eggs developed in both specimens, but testes not observed; a few spermatozoa, however, present at male funnels in holotype.

Remarks. The single, small, bifid penial setae, and the small, very slender atria are features which make this new species unique within the genus *Coralliodrilus*. The taxon is possibly parthenogenetic; although both specimens studied have mature eggs, none of them has sperm in their spermathecae, and only the holotype has a few (mature?) spermatozoa at the male funnels.

Distribution and habitat. Northern Territory. Intertidal coarse sand.

Etymology. Named for Dr J. Russell Hanley, who kindly invited me to the workshop in Darwin, and who provided most excellent working facilities at Mandorah.

Genus *Bathydrilus* Cook, 1970

Bathydrilus ampliductus sp. n.

(Fig. 8)

Type material. HOLOTYPE - NTM Wo 0044, from Ludmilla Creek (Station KAC-44). PARATYPE - SMNH Type coll. 4692, specimen from Station BH-28.

Description. Holotype 7.7 mm long, with about 53 segments (posterior end not fully differentiated); paratype 7.4 mm long, with 66 segments. Width at XI, 0.30 (holotype) and 0.21 mm (paratype). Prostomium somewhat triangular, about as long as wide. Clitellum well-developed, in holotype extending over X-XII, but thickest in XI-XII; less developed in paratype, extending over XI-XII only. Patches of other epidermal glands absent. Somatic setae (Fig. 8A) bifid, with upper tooth shorter and slightly thinner than lower; setae 32-55 µm long, 2-3 µm thick, (2)3 per bundle anteriorly, 2(3) per bundle in postclitellar segments. Penial setae (Fig. 8B; C: ps) somewhat sigmoid, and single-pointed or (occasionally) bifid with much reduced upper tooth. Penial setae 50-60 µm long, about 3.5 µm thick at middle, two or (at one side of holotype) three per bundle. Male pores paired, in line with somatic setae, posterior to middle of XI. Spermathecal pores lateral, in most anterior part of X.

Pharyngeal glands in (III)IV-VIII. Male genitalia (Fig. 8C) paired. Vas deferens (Fig. 8C: vd) not observed over whole length, but appears longer than atrium and ectally inflated, i.e. up to about 20 µm wide immediately before entering (ectal part of?) atrium. Atrium (Fig. 8C: a) ovoid or spindle-shaped, with thin outer layer of

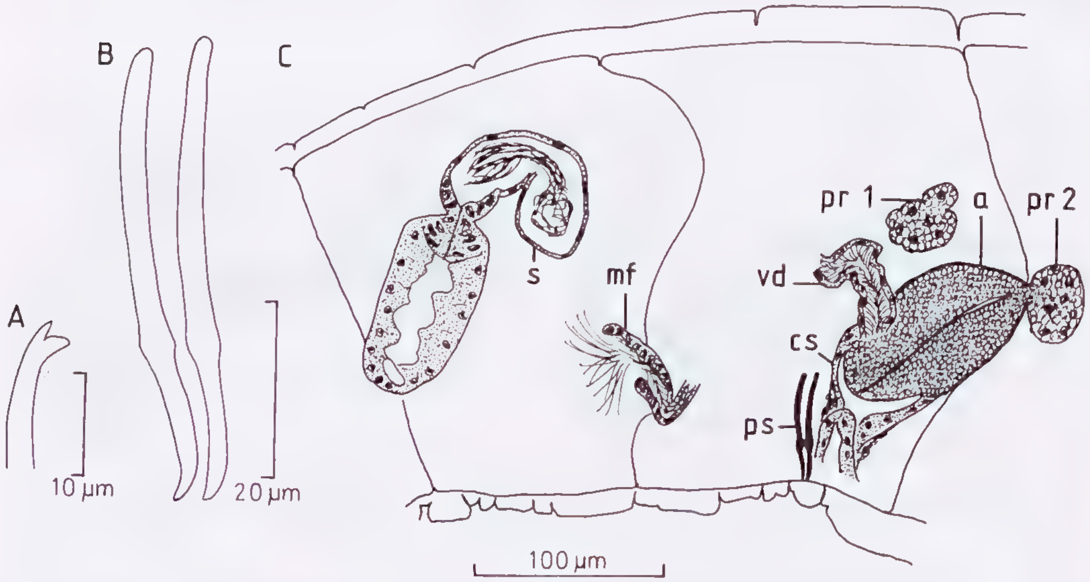

Fig. 8. *Bathydrilus ampliductus* sp. n.; **A**, somatic seta; **B**, penial setae; **C**, lateral view of spermatheca and male genitalia in X-XI.

some loose (?) muscle fibres. In holotype, atrium about 140 µm long, about 70 µm wide. Apex of atrium obliquely pointing towards posterior. Prostate glands small, anterior gland (Fig. 8C: pr 1) dorsal to and near entrance of vas deferens into atrium, posterior gland (pr 2) attached to apex of atrium. Atrium appearing to enter into copulatory sac (details unclear), opening (male pore) inconspicuous and small. Spermathecae (Fig. 8C: s) with conspicuous ducts, in holotype 95-100 µm long, 45-55 µm wide, and thin-walled, somewhat bipartite, ampullae, in holotype 105-130 µm long, 35-40 µm wide. In holotype, sperm somewhat bundled in spermathecal ampullae.

Remarks. The spermathecae of this species are similar to those of *B. torosus* Baker, 1983, a northwest Pacific species, which also has large (i.e., probably apomorphic) spermathecal ducts (Baker 1983: fig. 3C). However, the ratio between the length of the duct and the length of the ampulla is much greater in *B. torosus* than in *B. ampliductus*. In addition, *B. torosus* has no penial setae.

Distribution and habitat. Northern Territory. Known only from two intertidal rock pools, in coarse sediments.

Etymology. The name *ampliductus* alludes to the 'large' (Latin *amplis*) spermathecal ducts in this species.

Bathydrilus sp.
(Fig. 9)

Material examined. SMNH Main coll. 1442, specimen from Station 4.

Description. Length more than 10.2 mm, more than 52 segments; specimen not complete. Width at XI, 0.38 mm. Prostomium roundish, large and clearly set off from peristomium. Clitellum extending over ½X-XII, but no patches of epidermal glands in other segments. Somatic setae two to three per bundle anteriorly, one seta per 'bundle' in postclitellar segments. Anterior setae (Fig. 9A) 45-75 µm long, 2-3 µm thick, bifid with upper tooth distinctly shorter than lower. Postclitellar setae 60-65 µm long, 3-4 µm thick, bifid with rudimentary upper tooth, or sharply single-pointed (Fig. 9B). Penial setae (Fig. 9C; D: ps) about 100 µm long, 5-6 µm thick, three per bundle, single-pointed and somewhat curved. Bundles of penial setae enclosed in narrow setal sacs; glandular tissue not developed in these sacs. Tips of penial setae pointing towards mid-ventral line. Male pores paired, in line with ventral somatic setae, posterior to middle of XI (pore not shown in Fig. 9D; hole in atrium is an opitical section of lumen). Spermathecal pores paired, in lateral lines, anteriorly in X.

Pharyngeal glands in III-VII. Anterior septa not fortified by muscles. Male genitalia paired

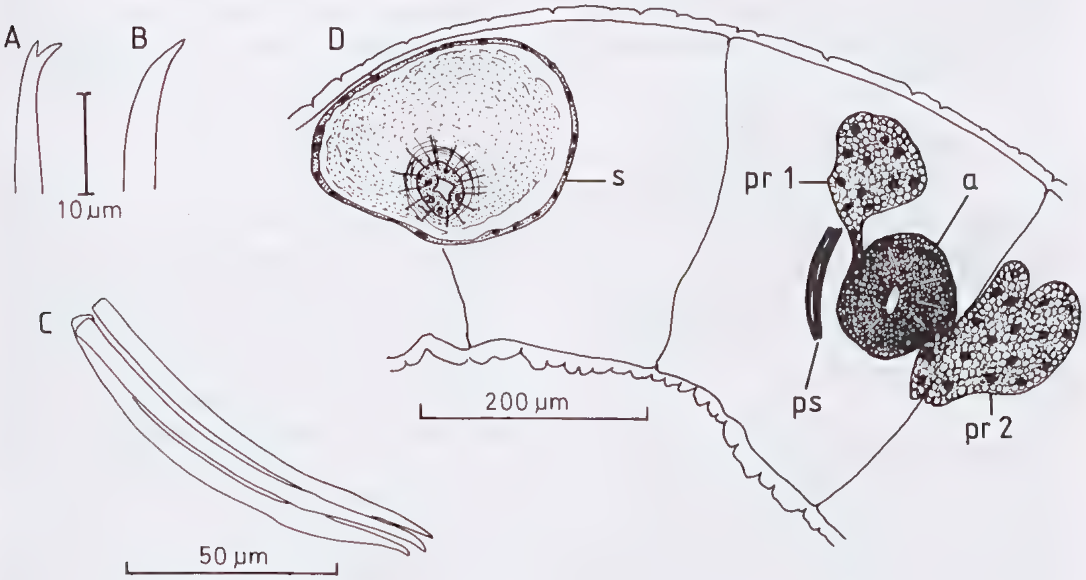

Fig. 9. *Bathydrilus* sp.; **A,** anterior somatic seta; **B,** posterior somatic setae; **C,** penial setae; **D,** lateral view of spermatheca and male genitalia in X-XI.

(Fig. 9D), but vasa deferentia not observed. Atrium (Fig. 9D: a) ovoid, erect, about 125 µm long, 100-105 µm wide, with thin outer (muscular) layer, and thick inner epithelium of tall, granulated and ciliated cells. Atrium opening directly to exterior through simple pore. Prostate glands (Fig. 9D: pr 1-2) large, two per atrium, but exact attachments with atrium not observed. Spermathecae (Fig. 9D: s) somewhat oval, about 225-250 µm long, with short, indistinct ducts. Spermathecae filled with amorphous secretion, but sperm absent.

Remarks. This single specimen probably represents a new species closely related to *B. superiovasatus* Erséus, 1981(a), and *B. munitus* Erséus, 1990(a), both known from other parts of Australia: the first from the Great Barrier Reef, the second from Victoria. It differs from *B. superiovasatus* by the presence of single-pointed setae in postclitellar segments, whereas the upper teeth are not completely reduced in setae of *B. superiovasatus*, and by its trisetal penial bundles, only two per bundle in *B. superiovasatus;* and from *B. munitus* by its single postclitellar setae, as opposed to, generally, two per bundle in *B. munitus*, and by its unmodified septa, compared to the heavily muscularized anterior septa in *B. munitus*.

However, the entrances of the vasa deferentia into the atria, and the attachments of the prostate glands, characters which are crucial for the discrimination of different species of *Bathydrilus*, are not visible in the only available specimen. Therefore, the species is not named here.

Distribution and habitat. Northern Territory. Intertidal sand.

Genus *Duridrilus* Erséus, 1983

Duridrilus piger Erséus, 1984

Duridrilus piger Erséus, 1984b: 154-155, figs 12-13. - Erséus 1990c: 285.

New material. NTM Wo 0045, specimen from Station 32. NTM Wo 0046, specimen from Station 38. SMNH Main coll. 1443-1444, 2 specimens (1 of which sectioned) from Station 18.

Remarks. *Duridrilus piger*, so far only reported from Hong Kong (Erséus 1984b, 1985), has a characteristic oval of muscle fibres, surrounding the area of the two male pores, ventrally in segment XI of sexually mature specimens. Such mucles have not been observed in any other species of *Duridrilus*.

The specimen from Station 32 is complete, but only partly mature; it is 8.6 mm long and consists of 55 segments. The other specimens lack their posterior ends. The new material conforms well with the original description.

Distribution and habitat. Northern Territory (new record), southern China; also collected in Queensland (Erséus, unpublished information). Subtidal, and intertidal rock pool, sediments, with at least some silt and/or clay, to at least 21 m depth.

Duridrilus pastoralis Erséus, 1990

Duridrilus pastoralis Erséus, 1990b: 71-72, fig. 14. - Erséus 1993: 362.

New material. NTM Wo 0047, specimen from Station 36. NTM Wo 0048-0049, 2 specimens from Station 37. SMNH Main coll. 1445-1447, 3 specimens (1 sectioned) from Station 37.

Remarks. This species has been recorded from Western Australia as well as the Great Barrier Reef (Erséus 1990b, 1993). It is fragile and none of the new specimens comprises more than the first 19 segments. The modified, postclitellar setae (Erséus 1990b: fig. 14B; see also Remarks for *D. darwinensis* below) of the Darwin worms are somewhat shorter (about 70-75 µm) than those of the previously studied material (85-105 µm). Otherwise, the new material conforms well with the original description.

Distribution and habitat. Northern Territory (new record), Queensland, Western Australia. Subtidal sand, to at least 15 m depth.

Duridrilus darwinensis sp. n.

(Fig. 10)

Type material. HOLOTYPE - NTM Wo 0050, from "Grab Station D87" (Station 32).

Description. Length 11.5 mm, with 54 segments. Width at XI, 0.26 mm. Prostomium small, retractile. Body wall of prostomium and I-II naked, cuticle thereafter covered by small particles, for most parts (particularly posterior to clitellum) forming numerous, leaf-shaped, papillae. Clitellum extending over XI-XII. Setae of II-VIII, two per bundle; those thereafter disposed singly, setae totally absent from XI. Preclitellar setae (Fig. 10A) 40-50 µm long, 1.5-2 µm thick, bifid with upper tooth thinner and shorter than lower. Posterior to clitellum, setae

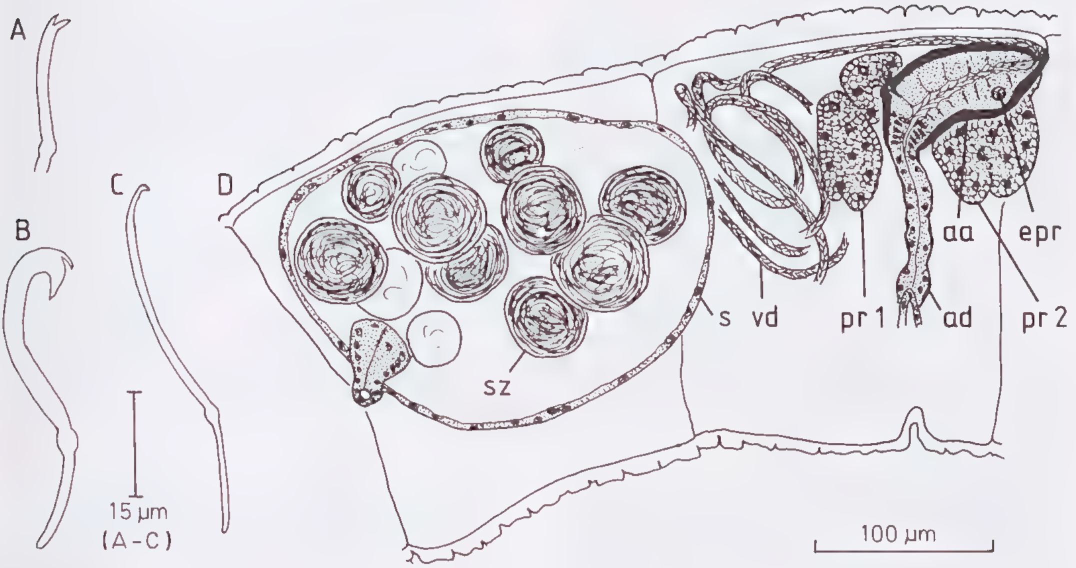

Fig. 10. *Duridrilus darwinensis* sp. n.; **A**, anterior seta; **B**, posterior seta; **C**, ventral seta from a segment near posterior end; **D**, lateral view of spermatheca and male genitalia in X-XI.

gradually modified, upper tooth becoming more reduced, lower tooth becoming larger and recurved towards setal shaft; fully modified setae (Fig. 10B) 35-45 µm long, about 3 µm thick, and with nodulus in clearly ental position. In some segments near posterior end of worm, ventral setae somewhat prolonged, slender, with hooked, single-pointed tips (Fig. 10C); these setae 50-60 µm long, 1-1.5 µm thick. Male pores paired, in line with ventral setae, posterior to middle of XI. Spermathecal pores paired, in line with ventral setae, in most anterior part of X.

Pharyngeal glands in III-V(VI?). Male genitalia (Fig. 10D) paired. Vas deferens thin-walled, ciliated, 5-6 µm wide, exceedingly long (only parts shown in Fig. 10D: vd), much coiled, entering apical end of atrium. Atrial ampulla (Fig. 10D: aa) spindle-shaped, 95-100 µm long, 45-55 µm wide, with apical end tilted over to the posterior, and with 4-5 µm thick outer layer of muscles, and ciliated inner epithelium. Atrial duct (Fig. 10D: ad) slender, indistinct, non-muscular, about 80-95 µm long, opening directly to exterior through simple, slit-like pore. Prostate glands appear compact (but not clearly seen in holotype), anterior one (Fig. 10D: pr 1) attached to ectal part of atrial ampulla, posterior one (pr 2) attached to sub-apical part of ampulla, at some distance from entrance of vas deferens. Spermathecae (Fig. 10D: s) voluminous, occupying most of X and XI, respectively, each with small, somewhat triangular ducts, about 50 µm long, about 30 µm wide at inner end, and thin-walled, somewhat oval, ampullae, 195-235 µm long, about 170 µm wide. Sperm as numerous, skein-like, spermatozeugmata; some of these enclosed in a distinct, hyaline lining.

Distribution and habitat. Northern Territory. Subtidal sand, 5 m depth.

Etymology. Named for Darwin Harbour, the area of the type locality.

Remarks. *Duridrilus darwinensis* is morphologically similar to both *D. pastoralis* Erséus, 1990b (known from Western Australia, Northern Territory as well as Queensland), and *D. kimi* Erséus, 1993 (known only from Western Australia). The male ducts and spermathecae are virtually identical in *D. darwinensis* and *D. pastoralis*, but the former species is discriminated by its shorter and less modified postclitellar setae (mid-body setae of *D. pastoralis* much prolonged and completely lacking upper teeth; Erséus 1990b:fig. 14B). In *D. kimi*, the corresponding setae do not appear to be modified (upper teeth reduced, but not more so than is normal for the genus), but as no complete worm of this species has yet been examined (holotype comprising segments I-XVI only; Erséus 1993), it is still possible that some postclitellar setae of *D. kimi* indeed are similar to those of *D. darwinensis*. Should this be so, *D. darwinensis* is still distinguished from *D. kimi* by its possession of numerous cuticular papillae (absent in *D. kimi*), and its longer and narrower atrial ducts (atrial ducts of *D. kimi* not well set off from atrial ampulla, instead tapering towards male pores).

The very slender, single-pointed setae present ventrally in a few posterior segments of *D. darwinensis* (Fig. 10C) has not been observed in any other member of the genus.

Genus *Olavius* Erséus, 1984
Olavius clavatus (Erséus, 1981)

Phallodrilus clavatus Erséus, 1981a: 20-21, figs 9-10, tables II-III.

Olavius clavatus - Erséus 1984a: 260, fig. 23. - Erséus 1993: 366-368.

New material. NTM Wo 0051, specimen from Station 4. NTM Wo 0052-0054, 3 specimens from Station 8. NTM Wo 0055-0056, 2 specimens from Station 21. SMNH Main coll. 1448-1457, 10 specimens (1 of which sectioned) from Station KAC-27.

Remarks. Originally described from the Great Barrier Reef (Erséus 1981a, 1984a), this species has also been reported from Rottnest Island in Western Australia (Erséus 1993). The new specimens conform well with the previous descriptions, with regard to general size (three complete worms are 8.1-11.5 mm long, with 45-65 segments), numbers of setae (somatic setae two per bundle throughout, penial setae five to six, occasionally four, per bundle), and morphology and dimensions of the genital organs (atria 80-105 μm long; spermathecae as in Erséus 1993: fig. 18C-E). On average, however, the penial setae are a little longer in the new material (about 60-70 μm) than in the old material (maximally 45-60 μm).

The new records of *O. clavatus* are from intertidal localities. The previous ones were all from subtidal sites.

Distribution and habitat. Northern Territory (new record), Queensland and Western Australia. Intertidal and subtidal sand, to at least 14 m depth.

Subfamily Limnodriloidinae
Genus *Doliodrilus* Erséus, 1984(a)
Doliodrilus diverticulatus Erséus, 1985

Doliodrilus diverticulatus Erséus, 1985: 144-146, figs 10-11.

New material. NTM Wo 0057, specimen from Station 31. NTM Wo 0058, specimen from Station BH-51. SMNH Main coll. 1458-1459, 2 specimens (1 sectioned) from Station BH-54.

Remarks. *Doliodrilus diverticulatus* has a large, unpaired, oesophageal diverticulum in segment IX, a unique trait within the genus, and a pair of posteriorly directed blind sacs on the atrial ducts; the latter feature is an apomorphy

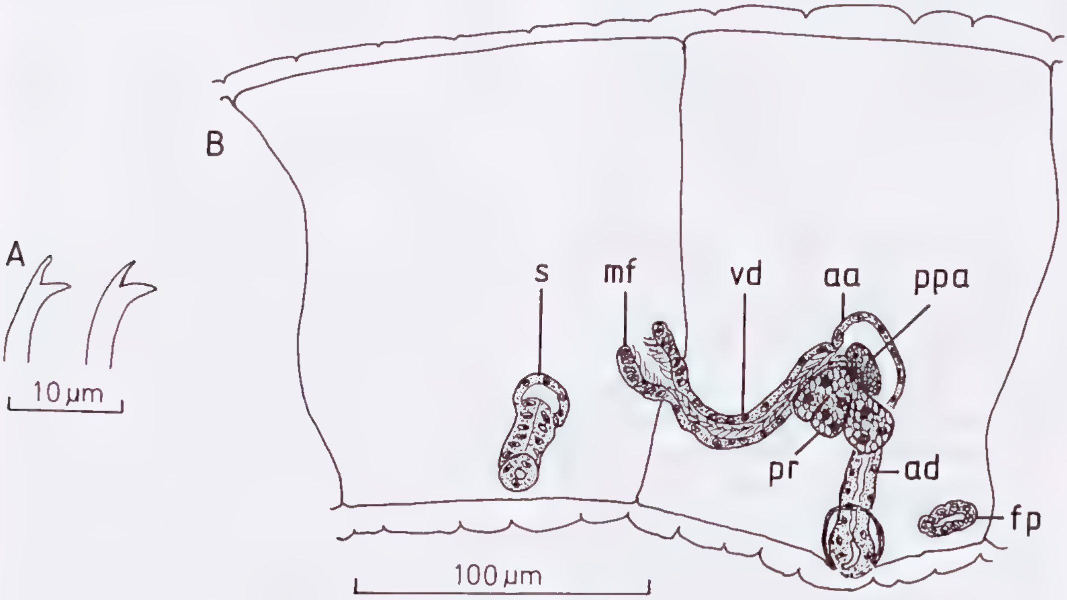

Fig. 11. *Tectidrilus arabicus* Erséus, 1985; **A**, setae; **B**, lateral view of genitalia in X-XI.

of *Doliodrilus* (Erséus 1985; Erséus and Milligan 1988). The new specimens conform well with the original description. Two specimens are complete, 7.7 and 8.7 mm long, with 49 and 46 segments, respectively.

Previously studied specimens of *D. diverticulatus* all lacked sperm in their spermathecae. One of the new worms is postcopulatory, with spermathecae (at least one of them) about 150 µm long, 35 µm wide, and containing a coiled bundle of sperm.

Distribution and distribution. Northern Territory (new record), Saudi Arabia (Persian/Arabian Gulf). The species was previously known only from a subtidal, brackish-water site, in the bank of a tidal channel in mangroves. This appears to be a habitat very similar to those of the new material, although at the time of collection (dry season), the Darwin mangrove creeks probably were at full coastal salinities.

Genus *Tectidrilus* Erséus, 1982

Tectidrilus arabicus Erséus, 1985

(Fig. 11)

Tectidrilus arabicus Erséus, 1985: 150-151, fig. 15.

New material. NTM Wo 0059, specimen from Station 18.

Description of new material. Length 4.8 mm, 29 segments. Width at XI, 0.20 mm. Prostomium small, much shorter than wide, not retracted into peristomium. Body wall with some scattered fine particles on cuticle anteriorly, densely papillated in postclitellar segments. Clitellum extending over XI and anterior 1/3 of XII, but not fully developed. Setae (Fig. 11A) up to 45 µm long, up to 2 µm thick, two per bundle in II-VIII, 'bundles' unisetal thereafter; but setae totally absent from X-XI, and occasionally also from other segments. Setae with slender, almost equally long and thick teeth, or with upper tooth slightly shorter and thinner than lower. Male pores paired, in line with ventral setae, immediately posterior to middle of XI. Female pores (Fig. 11B: fp) clearly visible, located ventral to lateral lines (not as far down the sides of worm as male pores), in most posterior part of XI. Spermathecal pores paired, in line with ventral setae, in middle of X.

Pharyngeal glands well developed in IV-V. Pair of small oesophageal diverticula present in anterior part of IX. Male genitalia (Fig. 11B) paired. Vas deferens (Fig. 11B: vd) about 10 µm wide, as long as, or possibly somewhat longer than, atrium. Atrium club-shaped, with thin, non-muscular, outer layer. Atrial ampulla (Fig. 11B: aa) oval, simple, 35-40 µm long, about 18 µm wide, with indistinct, small, prostatic pad (ppa). Prostate gland (pr) small, lobed. Atrial duct (ad) about 35 µm long, 10-12 µm wide, without any distinct granulation. Atrial duct opening to exterior through simple pore; most ectal part of duct enclosed in small, thin-walled sac, but pseudopenial papilla not present. Spermathecae (Fig. 11B: s) small (not fully developed?), totally about 40 µm long, with small ampulla, about 18 µm wide, devoid of sperm.

Remarks. *Tectidrilus* contains several small, papillated species, with largely the same morphological outline of the genitalia. The present specimen does not appear to be fully developed (clitellum not distinct, spermathecae without sperm), and its taxonomic identification is somewhat tentative.

The genus has never been recorded from Australia before, but three of its marine species (*T. arabicus* Erséus, 1985, from Saudia Arabia (Erséus 1985), *T. pictoni* (Erséus, 1984) from China (Erséus 1984b, 1990c; Erséus *et al.* 1990), and *T. bori* (Righi and Kanner, 1979) from Hawaii (Erséus and Davis 1989)) are known from other parts of the Indo-Pacific region and could be expected to occur in north Australian waters as well. The new material fits the description of *T. arabicus* better than those of the other two species. *Tectidrilus arabicus* is papillated (the other two only have a 'dusty' body wall), and lacks penial or pseudopenial papillae (such papillae present in *T. pictoni* and *T. bori*). Moreover, *T. bori* has accessory 'copulatory glands' in the posterior part of XI, structures that are absent in *T. arabicus* (and in *T. pictoni*).

Distribution and habitat. Northern Territory (new record), Saudi Arabia (Persian/Arabian Gulf). Intertidal (rock pool) and subtidal sands.

Genus *Smithsonidrilus* Brinkhurst, 1966

Smithsonidrilus minusculus (Erséus, 1983)

Marcusaedrilus minusculus Erséus, 1983b: 30-31, fig. 5, table I. - 1990b: 78-79, fig. 17.

Limnodriloides claviger (*partim*) Erséus, 1982: 221-222 (*nec* fig. 6). - Erséus and Davis 1989: 92-93, fig. 12.

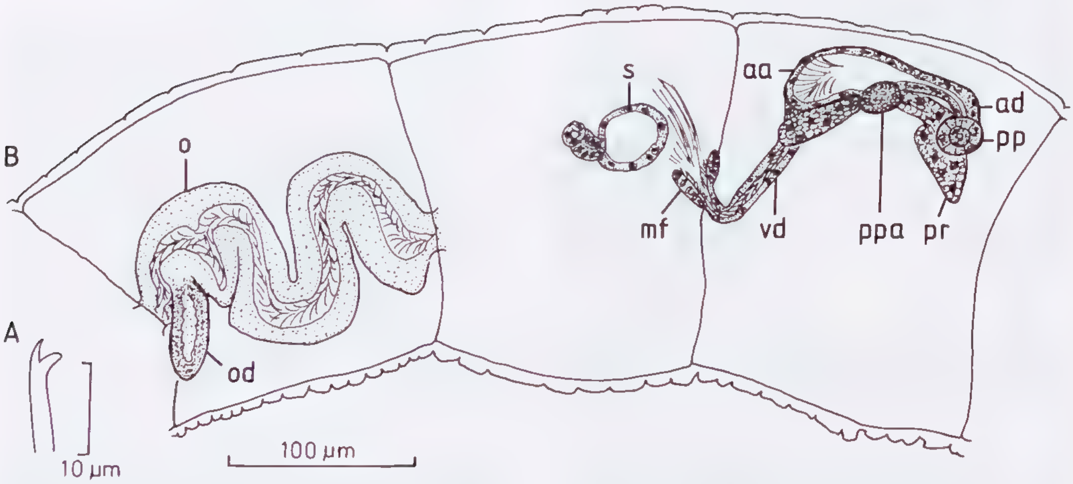

Fig. 12. *Smithsonidrilus ludmillae* sp. n.; **A**, seta; **B**, ventro-lateral view of oesophagus in IX, spermatheca in X, and male genitalia in XI.

Smithsonidrilus minusculus - Erséus 1990d: 289-291, fig. 32; - Erséus 1992b: 174-175, fig. 12A-B; - Erséus 1993: 379-380, fig. 24.

New material. NTM Wo 0060, specimen from Station 15.

Remarks. This widespread species has been described several times, from various parts of the world (references above). Some of the specimens from Western Australia lacked spermathecae (Erséus 1993), but the Darwin individual has a pair of (small) spermathecae in the expected position. The worm is 4.1 mm, with 28 segments, i.e., within the ranges noted for *S. minusculus* before, but the posterior end appears amputated (and healed).

Distribution and habitat. Northern Territory (new record), Queensland, Western Australia, southern China, Hawaii, Bermuda, Belize. Intertidal and subtidal sands, to at least 15 m depth.

Smithsonidrilus ludmillae sp. n.
(Fig. 12)

Type material. HOLOTYPE - NTM Wo 0061, from Ludmilla Creek (Station KAC-44). PARATYPE - SMNH Type coll. 4693, specimen from Station 29.

Description. Holotype 4.3 mm long, with 31 segments; paratype 5.0 mm, 36 segments. Width at XI, 0.22 (holotype) and 0.29 mm, respectively; both specimens much narrower (down to 0.07 mm) posteriorly. Prostomium rounded triangular, with small apical papilla. Clitellum extending over XI and anterior 2/3 of XII in paratype, poorly developed in holotype. Setae (Fig. 12A) bifid, with equally long teeth, but upper tooth slightly thinner than lower. Setae 25-50 µm long, 1-2 µm wide, (1)2-5 per bundle anteriorly, (1)2 per bundle in postclitellar segments, but absent ventrally from X-XI. Male pores paired, in line with ventral setae, posterior to middle of XI. Spermathecal pores paired, in line with ventral setae, in middle of X.

Pharyngeal glands in IV-V. Oesophageal diverticula (Fig. 12B: od) minute, compared with those of other species, in anteriormost IX. Male genitalia (Fig. 12B) paired. Vas deferens (Fig. 12B: vd) maximally 13-14 µm wide, about as long as atrium, entering apical end of atrial ampulla. Atria club-shaped, consisting of somewhat ovoid ampulla, and cylindrical duct. Atrial ampulla (Fig. 12B: aa) 60-68 µm long, 26-36 µm wide, non-muscular and thin-walled, with long cilia inside ental part, and with conspicuous, round, bulging prostate pad (ppa) at ectal end. Lobed (more or less bipartite) prostate gland (pr) communicating with this pad. Atrial duct (Fig. 12B: ad) 60-90 µm long, 15-20 µm wide, non-muscular, with some granulation in inner epithelium. Atrial duct terminating in simple pseudopenis (Fig. 12B: pp), merely as a small indistinct invagination; in holotype, both pseudopenes everted, forming pair of small papillae. Spermathecae (Fig. 12B: s) poorly developed and devoid of sperm in holotype; in paratype consisting of short ducts and large ampullae (exact shape and size not clear), each contain-

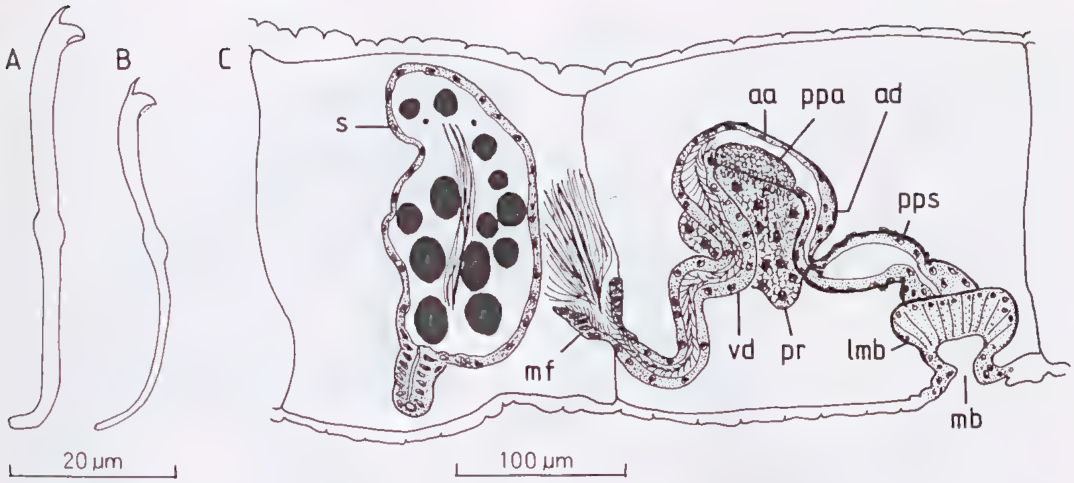

Fig. 13. *Smithsonidrilus arduus* sp. n.; **A**, anterior seta; **B**, posterior seta; **C**, lateral view of spermatheca and male genitalia in X-XI.

ing two discrete bundles of sperm (or spermatozeugmata?).

Remarks. The number of setae per bundle in the preclitellar segments is lower in the holotype (up to three per bundle) than in the paratype (up to five per bundle). However, the appearance of the setae, oesophageal diverticula (very small), and male ducts (with spacious, ciliated atrial ampullae and bulging prostate pads) is virtually identical in the two worms.

Smithsonidrilus ludmillae resembles *S. minusculus* (see above), but its atrial ampullae are more inflated and with more prominent prostatic pads than those of the latter species. If the large spermathecae of the paratype (with its discrete spermatozeugma-like sperm bundles) prove to be typical for *S. ludmillae*, this will also discriminate this new species from *S. minusculus*. When present (absent in material from Rottnest Island; see Erséus 1993), the spermathecae tend to be small in the latter taxon. Finally, the oesophageal diverticula are smaller in *S. ludmillae* than in any other species of *Smithsonidrilus*.

Distribution and habitat. Northern Territory. Intertidal, somewhat silty sand.

Etymology. Named *ludmillae* for Ludmilla Creek, the type locality.

Smithsonidrilus arduus sp. n.
(Fig. 13)

Type material. HOLOTYPE - NTM Wo 0062, from Weeds Reef (Station 36). PARATYPES - NTM Wo 0063-0064, 2 specimens from type locality; SMNH Type coll. 4694-4695, 2 specimens from type locality; and SMNH 4696-4698, 3 specimens from Station 23.

Other material examined (author's collection). Three specimens from type locality.

Description. Length more than 7 mm, more than 36 segments; no specimens complete. Width at XI, 0.23-0.30 mm; one specimen wider, but almost squashed. Prostomium variable, round or triangular. Clitellum extending over XI-XII in one specimen, not developed in others. Setae (Fig. 13A-B) bifid, with upper tooth distinctly thinner and shorter than lower, and with indistinct subdental ligaments; inner ends of setae characteristically thin in posterior segments (Fig. 13B). Setae 50-65 µm long, 1.5-3 µm thick (at node), (1)2-3 per bundle anteriorly, one or two per bundle in postclitellar segments, but ventral setae absent from X-XI. Male pore an unpaired bursa, with a squarish opening, mid-ventrally in posterior part of XI. Spermathecal pores paired, in line with ventral setae, in middle of X.

Pharyngeal glands in IV-V. Oesophageal diverticula (in IX) not large, originating from oesophagus at middle of segment. Male genitalia (Fig. 13C), except unpaired male bursa, paired. Vas deferens (Fig. 13C: vd) 20-23 µm wide, thick-walled, somewhat longer than and entering apical end of atrium, but transition between vas and atrial ampulla indistinct. Atrium cylindrical and non-muscular. Atrial ampulla (Fig. 13C: aa) about 65-75 µm long, 25-28 µm wide, possibly with few long cilia inside ental end (?depending on where vas ends), ampulla

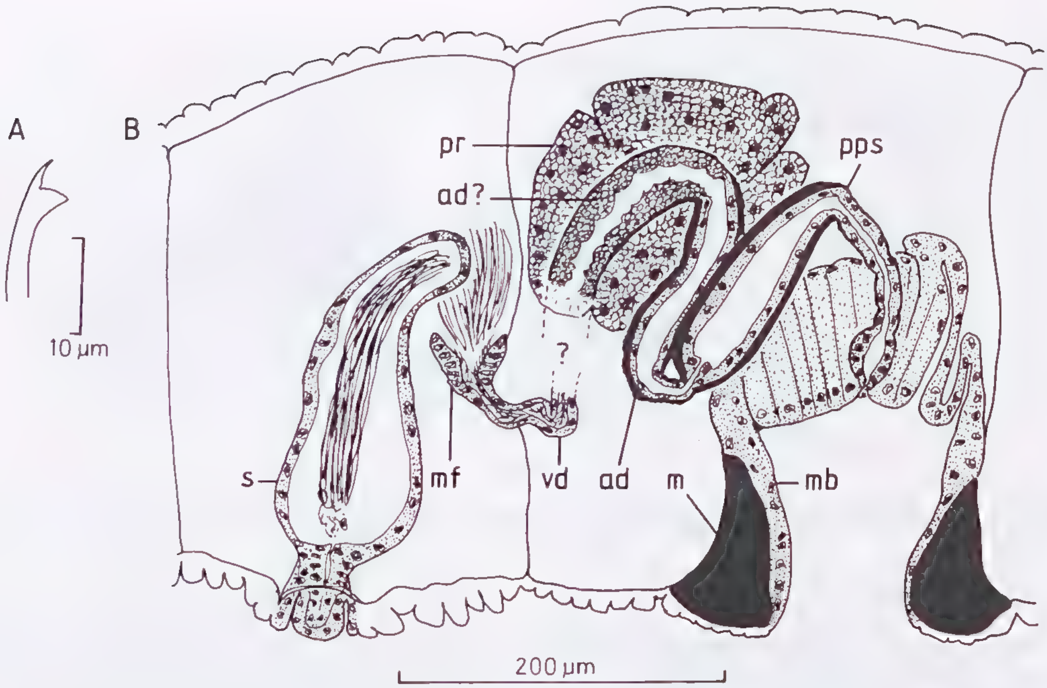

Fig. 14. *Smithsonidrilus convexus* sp. n.; **A**, seta; **B**, lateral view of spermatheca and male genitalia in X-XI.

almost filled with elongate prostatic pad (ppa). Prostate gland (Fig. 13C: pr) broadly attached to this pad. Atrial duct (Fig. 13C: ad) about 50 µm long, about 20 µm wide, non-granulated, and tapering before terminating into pseudopenial sac (pps). Latter bipartite, somewhat club-shaped, 80-100 µm long, maximally 33-38 µm wide, with thin, but distinct, outer layer of muscles. Pseudopenial sacs of both sides entering pair of conspicuous, thick-walled, lateral lobes of male bursa (Fig. 13C: lmb). Spermathecae (Fig. 13C: s) consisting of distinct ducts about 40 µm long, and sacciform ampullae up to about 200 µm long, when fully developed. Ampullae filled with large (?secreted) granules, even at early development; in postcopulatory specimens, each ampulla also with one to few bundles of long spermatozoa.

Remarks. Three species of *Smithsonidrilus* (*S. edgari* Erséus, 1993, from Western Australia, *S. convexus* sp. n. (described below) and *S. arduus*) share the character combination of (1) an unpaired male bursa, (2) paired spermathecal pores, and (3) a pair of club-shaped pseudopenial sacs opening into lateral lobes of the male bursa; of which (1) and (3) are likely to be apomorphic features. *Smithsonidrilus arduus* is easily distinguished from *S. edgari* by its spermathecae (those of *S. edgari* have a long duct-like portion, followed by a narrow ampulla of about the same length; Erséus 1993: fig. 26B), but there also appears to be a fundamental difference in the inner morphology of the atria. The atrium of *S. edgari* consists of a small, ovoid ampulla, containing a roundish prostatic pad, and a duct, the first part of which is heavily granulated (Erséus 1993: fig. 26B); this is a "typical" limnodriloidine atrium. In *S. arduus*, however, the atrial ampulla is elongate and contains a correspondingly prolonged prostatic pad, while the first part of the atrial duct is not granulated (Fig. 13C). A similar comparison is difficult to make between *S. arduus* and *S. convexus*, as the atrial features are not fully visible in the material of the latter taxon (see Remarks for *S. convexus* below). *Smithsonidrilus convexus*, however, has more prolonged pseudopenial sacs than those of *S. arduus*, and an unusually elaborate male bursa (Fig. 14B: mb).

Distribution and habitat. Northern Territory. Intertidal and barely subtidal sand.

Etymology. Named *arduus* (Latin for 'difficult, troublesome'), for the complicated male ducts, which are hard to make out in most specimens.

Smithsonidrilus convexus sp. n.

(Fig. 14)

Type material. HOLOTYPE - NTM Wo 0065, from Lee Point (Station 3).

Description. Length more than 2.9 mm, more than 16 segments; posterior end lacking. Width at XI, 0.39 mm. Prostomium about as long as wide, roundish, with small apical papilla. Clitellum short, extending over XI and anterior 2/3 of XII only. Setae (Fig. 14A) bifid, with upper tooth thinner and shorter than lower, and without (obvious) subdental ligament. Setae 40-60 µm long, 2.5-3 µm thick, three to four per bundle anteriorly, totally absent from XI, two per bundle in XII-XVI (rest of worm missing). Male pore unpaired, as a mid-ventral bursa, posterior to middle of XI. Spermathecal pores paired, but ventral to lines of ventral setae, in middle of X.

Pharyngeal glands in IV-V. Oesophageal diverticula slender, originating from oesophagus posterior to middle of IX. Male genitalia (Fig. 14B), except male bursa, paired. Vas deferens (Fig. 14B: vd) entally about 15 µm wide; ectal parts not observed. Details of atrial ampulla not clear in available material, visible parts of atrium about 300 µm long, and probably comprising atrial duct only (see Remarks). Duct consisting of somewhat granulated, non-muscular ental part (Fig. 14B: ad?), about 35 µm wide, and non-granulated, muscular ectal part (ad), about 30 µm wide. Large lobed prostate gland (Fig. 14B: pr) present, but attachment with atrium not discerned. Atrial duct terminating in slender, duct-like pseudopenial sac (Fig. 14B: pps), about 280 µm long, entally heavily muscular, 42 µm wide, ectally non-muscular, only 18-25 µm wide. Pseudopenial sacs of two sides opening near each other at inner end of conspicuous male bursa (Fig. 14B: mb). Bursa 180-190 µm wide, about 210 µm deep; inner wall very thick, non-muscular, and may act as large copulatory papilla when everted, outer part of bursa surrounded by powerful ring of muscles (Fig. 14B: m). Spermathecae (Fig. 14B: s) with thin-walled ampullae, about 230 µm long, basally 90-95 µm wide, tapering towards inner end; ducts short, ending in eversible vestibules; latter everted and protruded as papillae at both sides of holotype. Sperm as one large, broad bundle in each spermathecal ampulla; at inner end of this bundle in one of spermathecae (the one not depicted in Fig. 14B), spermatozoa arranged in several thin aggregates which may be simple spermatozeugmata.

Remarks. Unfortunately, only one specimen of this species is available, and it does not show all details of the male genital system. For instance, it is not clear whether the granulated portion of the male duct (Fig. 14B: ad?) is the ental part of the atrial duct, or an elongate atrial ampulla similar to that of *S. arduus* described above (Fig. 13C). In the latter case, what is depicted as a granulated epithelium inside the duct may in fact include an elongate prostatic pad.

Nevertheless, *S. convexus* is undoubtedly a new taxon, closely related to but clearly separated from *S. edgari* and *S. arduus*. The main differences are that in *S. convexus*: (1) the copulatory sacs are ectally prolonged into slender ducts, whereas these sacs are club-shaped or pear-shaped in *S. edgari* and *S. arduus*; (2) the male bursa is much larger and more muscular; and (3) the spermathecal pores more complex than in the other two species (see also Remarks for *S. arduus* above). All three characters appear to be autapomorphies of *S. convexus*.

Distribution and habitat. Northern Territory. Intertidal gravelly sand.

Etymology. Named *convexus* (Latin for 'arched, vaulted') for the large, invaginated, male bursa.

Smithsonidrilus irregularis (Erséus, 1983)

Marcusaedrilus irregularis Erséus, 1983b: 33-34, fig. 9, table I. - 1990c: 289-291, fig. 12.

Smithsonidrilus irregularis - Erséus 1990d: 289.

Smithsonidrilus cf. *irregularis* - Erséus 1993: 383-384, fig. 27.

New material. NTM Wo 0066, specimen from Station 3. SMNH Main coll. 1460-1461, 2 specimens, from Stations 15 and KAC-44, respectively.

Remarks. This small species has been recorded from various parts of the Indo-West Pacific region. The present specimens are 2.8-4.4 mm long, with 35-44 segments, and their spermathecae are as those of the previously studied material from the Great Barrier Reef and Hong Kong (Erséus 1983b: fig. 9B; 1990c: fig. 12B). The worm from Western Australia tentatively attributed to this species had a different kind of spermatheca (see Erséus 1993).

Distribution and habitat. Northern Territory (new record), Queensland, Western Australia, southern China. Intertidal and subtidal sands; also in brackish water.

Genus *Limnodriloides* Pierantoni, 1903
Limnodriloides rubicundus Erséus, 1982

Limnodriloides rubicundus Erséus, 1982: 226-228, fig. 10. - Erséus 1987a: 273-274; -Erséus and Davis 1989: 93-94, fig. 13; - Erséus 1990d: 288; - Erséus 1992b: 173-174, fig. 11; -Erséus 1993: 375-377, fig. 23.

New material. NTM Wo 0067, specimen from Station 30. SMNH 1462, specimen from Station 30. SMNH 1463, sectioned specimen from Station 31. SMNH 1464, specimen from Station KAC-44.

Remarks. This wide-spread species was previously known from both Western Australia and the Great Barrier Reef (Erséus 1993), so its occurrence in the Darwin area was expected. The new specimens have their male pores located slightly ventral to the lines of the ventral setae, which conforms with the earlier observations on Australian material (Erséus 1993); in other parts of the world, the male pores of *L. rubicundus* are in line with the ventral setae.

Only the specimen from Station 3 is complete. It is 5.9 mm long, with 50 segments. The worm from Station 30 has relatively large atria (with ampullae about 125 µm long) and spermathecae, the latter containing distinct spindle-shaped sperm bundles (?spermatozeugmata). The specimens from the other stations have smaller atria (ampullae maximally 75 µm long) and spermathecae, with less organized sperm in the latter. This range of variation was reported for *L. rubicundus* throughout the world before (Erséus 1982, 1992b, 1993; Erséus and Davis 1989), but at the same time it is a warning that the taxon may be a complex of more than one species.

Distribution and habitat. Northern Territory (new record), Queensland, Western Australia, Fiji, southern China, Hawaii, Barbados, Venezuela, Belize, Bahamas, Bermuda, east coast of United State (Florida through Delaware). Intertidal and subtidal, often muddy, fine, sediments, to at least 74 m depth.

Limnodriloides biforis Erséus, 1990

Limnodriloides biforis Erséus, 1990c: 295-297, fig. 15.

New material. NTM Wo 0068-0070, 3 specimens: 1 from each of Stations 29, KAC-6 and KAC-44. SMNH 1465-1469, 5 specimens from Station 4.

Remarks. This species was previously known only from the type locality in Hong Kong (Erséus 1990c). It belongs to a group of species within *Limnodriloides* characterized by (1) modified, ectally grooved, spermathecal setae, (2) slightly modified bifid setae ("penial setae") associated with the male pores, the latter being either paired or unpaired, and (3) large prostatic pads that typically fill most of the lumina of the atrial ampullae. *Limnodriloides biforis* has an unpaired male as well as spermathecal pore, and an unpaired, pedunculate, papilla in front of the spermathecal pore.

The new material conforms well with the original description, even with regard to most dimensional features. Two specimens are unexpectedly short (4.1 and 4.7 mm, with 28 and 35 segments, respectively), but their posterior ends appear regenerated as if they have been amputated. The spermathecal setae, one at each side of worm in X, are 160-205 µm long. The short, bifid penial setae, located in an unpaired, midventral, thick-walled epidermal invagination in most posterior part of XI, are consistently two per bundle rather than four per bundle as in the Hong Kong material.

In VIII and the margins of VII and IX of all of the Darwin individuals, the epidermis is markedly thickened on the ventral side of the worm. The epidermal cells are taller than normal, apparently of a glandular nature, but they are not as granulated as the clitellar cells. The exact function of this pad-like area is unknown. Such a thickening could not be seen in three reexamined specimens from Hong Kong in the author's collection.

Distribution and habitat. Northern Territory (new record), southern China. Intertidal and barely subtidal, largely silty or muddy sediment; also in brackish water.

Limnodriloides fraternus Erséus, 1990

Limnodriloides fraternus Erséus, 1990c: 293-294, fig. 14A-C, G.

New material. NTM Wo 0071, specimen from Station BH-54. NTM Wo 0072-0073, 2 specimens from Station BH-60. SMNH Main coll. 1470-1472, 3 specimens from Station BH-60.

Brief description of new material. Length (three complete specimens) 7.5-7.8 mm, 44-51 segments. Prostomium triangular, muscular. Clitellum extending over XI-XII. Setae up to

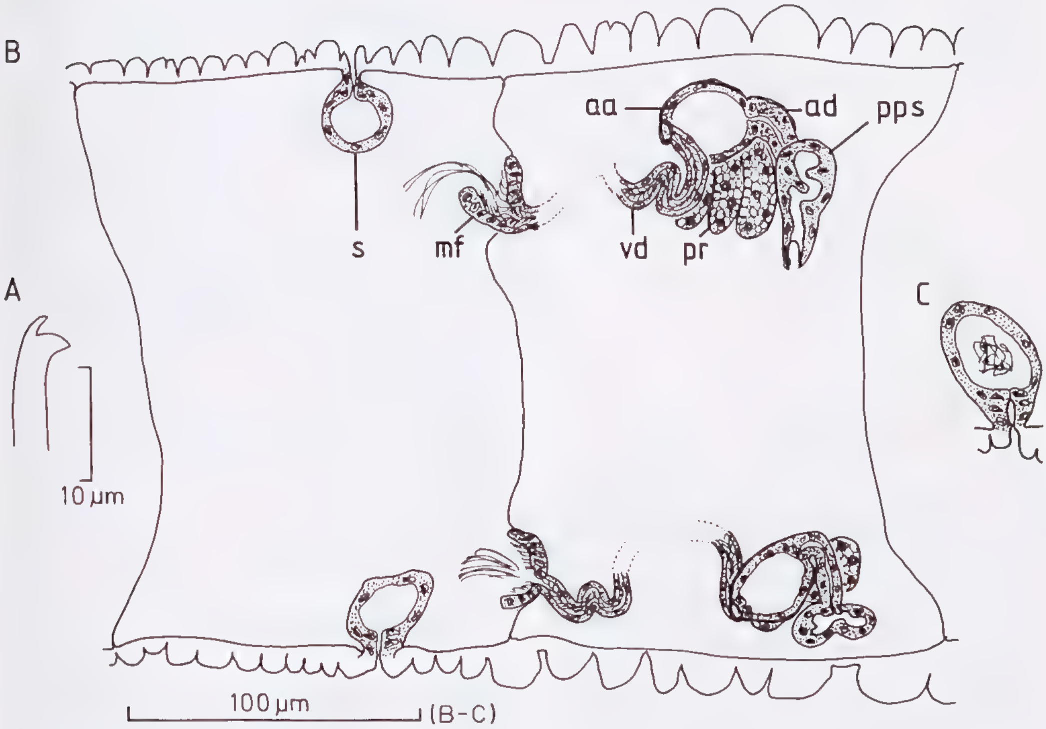

Fig. 15. *Limnodriloides lateroporus* sp. n.; **A**, seta; **B**, ventral view of spermathecae and male genitalia in X-XI (holotype); **C**, spermatheca of another specimen (paratype).

55-58 µm long, up to 3 µm thick, (1)2-4 per bundle anteriorly, often one per 'bundle' in clitellar region, 2(3) per bundle thereafter. Setae bifid, with upper tooth longer than lower. Male pores paired, but very close together ventrally in XI. Spermathecal pore unpaired, mid-ventral in middle of X. Preclitellar septa muscular. Vasa deferentia, atria and spermathecae as described by Erséus (1990c).

Remarks. *Limnodriloides fraternus* and *L. toloensis* Erséus, 1984b are two very similar species, both previously known only from Hong Kong. They differ in general size, setal morphology and dimensions, and arrangement of spermathecal pores (clearly unpaired in *L. fraternus*, paired, but very close together in *L. toloensis*; Erséus 1990c).

The new material conforms to almost everything in the original description, but the setae of the Darwin worms are somewhat intermediate between those of *L. fraternus* and *L. toloensis* from Hong Kong (see Erséus 1990c: fig. 14A-F). Their upper teeth are longer than the lower ones, but not twice as long as they are in segments of the original material of *L. fraternus* (Erseus 1990c: fig. 14C).

It was noted before (Erséus 1990c) that *L. fraternus* has a somewhat muscular prostomium. The strong muscles in the anterior septa described here, however, were not originally observed. A re-examination of material in my collection showed that these muscles are well developed in specimens from Hong Kong also.

Distribution and habitat. Northern Territory (new record), southern China. Intertidal mud.

Limnodriloides lateroporus sp. n.
(Fig. 15)

Type material. HOLOTYPE - NTM Wo 0074, from Ludmilla Creek (Station KAC-44). PARATYPES - NTM Wo 0075-0078, 4 specimens from type locality; SMNH Type coll. 4699-4701, 3 specimens from type locality; SMNH Type coll. 4702-4703, 2 specimens, from Stations 9 and 27, respectively.

Other material (author's collection). Four specimens: 3 from Station 15, 1 from Station 21.

Description. Length (2.6)3.9-8.2 mm, (25)34-46 segments; shortest specimen with amputated

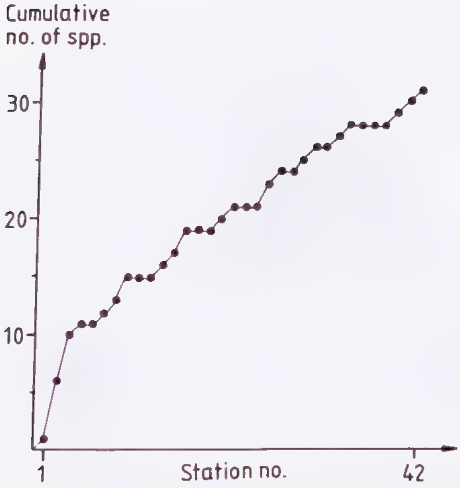

Fig. 16. A cumulative species/station curve for 33 stations in the Darwin Harbour area sampled by the author (Stations 1 through 42 listed in this paper).

(healed) posterior end. Width at XI, 0.19-0.36 mm. Prostomium variable, but often shorter than wide. Clitellum extending over ½X-XII, when fully developed. Setae (Fig. 15A) bifid, with upper tooth thinner and shorter than lower. Setae 50-60 µm long, 2-3 µm thick, 2-3(4) per bundle anteriorly, (1)2 per bundle in postclitellar segments; but absent ventrally from XI (sexually mature specimens). Male pores paired, in line with ventral setae, posterior to middle of XI. Spermathecal pores paired, in lateral lines, in middle of X.

Pharyngeal glands in IV-V. Oesophageal diverticula small, originating from oesophagus immediately anterior to middle of IX. Male genitalia (Fig. 15B) paired. Vas deferens (Fig. 15B: vd) 11-14 µm wide, longer than atrium, entering apical end of latter. Atrium club-shaped, somewhat erect or (more often) strongly curved. Atrial ampulla (Fig. 15B: aa) ovoid (when dilated), or somewhat bipartite and wrinkled, 33-40 µm long, 18-34 µm wide, with very thin outer layer of muscles, and devoid of cilia inside. Prostatic pad (not shown in Fig. 15B) indistinct when atrial ampulla is dilated, more pronounced when ampulla is wrinkled (then appearing as bulge on ampulla). Prostate gland (Fig. 15B: pr) lobed, small. Atrial duct (Fig. 15B: ad) short and simple, 30-50 µm long, 13-30 µm wide, non-muscular, with varying degree of granulation. Atrial duct opening into lateral wall of small invagination of body wall (pseudopenial sac; Fig. 15B: pps); external opening of invagination (=male pore) inconspicuous. Spermathecae (Fig. 15B: s) 38-50 µm long, 30-45 µm wide, each consisting of very short duct, and round to ovoid ampulla. In postcopulatory specimens, sperm as loose bundle or round mass in spermathecae.

Remarks. This species resembles *L. hrabetovae* Erséus, 1987(b), known only from the Mediterranean Sea. The latter taxon also has small, somewhat 'crumpled up' male ducts, and small ovoid spermathecae, and its setal pattern is more or less identical with that of the new species. *Limnodriloides lateroporus* is distinguished from *L. hrabetovae* by its lateral (instead of ventral) spermathecal pores.

Distribution and habitat. Northern Territory. Intertidal and barely subtidal, often somewhat muddy, sands.

Etymology. Named *lateroporus* for the lateral position of the spermathecal pores.

ECOLOGY AND HABITAT

With regard to abundance of Tubificidae, Darwin Harbour proved disappointing. Many of the sandy habitats of the area are unstable and mobile due to the powerful tidal currents (tidal amplitude about 8 m), others are strongly impacted by the great deposition of terrigenous silt. Most of the sediments of Darwin Harbour are thus either too coarse and clean, or too fine and compact, to favour the establishment of a rich interstitial fauna. Tubificids are present here and there, but mostly in low numbers. The most successful sampling was made in marginal and patchy habitats of largely coarse, organically enriched sediments of intertidal reefs and rock pools, in the coarse sediments of intertidal creeks, and in some muds and sands of mangroves.

The scarcity of suitable habitats in the Darwin Harbour is probably the major explanation why the 185 specimens studied in this paper are only about one fifth of the number of tubificid specimens collected during a comparable workshop at Rottnest Island, Western Australia, in 1991 (Erséus 1993); and yet the Darwin study includes material originating from the efforts of two additional oligochaete collectors (K.A. Coates, B. Healy), who were not present at Rottnest Island. At Darwin, the number of species per station was low, on average only 1.8 (maximum 6 spp.; Station KAC-44), excluding

Table 1. Known geographical distribution of 35 species of marine Tubificidae recorded from the Darwin Harbour area, Northern Territory (N.T.). Other abbreviations: H.K., Hong Kong; QLD, Queensland; W.A., Western Australia. (*Ainudrilus stagnalis* sp. n., a freshwater species, and the unnamed *Bathydrilus* sp. are excluded.)

Category, species:	W.A.	QLD	H.K.	Other areas
CIRCUMTROPICAL/SUBTROPICAL (5 spp., 14%)				
?Heronidrilus cf. *gravidus*				Atlantic
Jamiesoniella athecata		x	x	Atlantic
Pectinodrilus molestus		x	x	Fiji, Hawaii, Atlantic
Smithsonidrilus minusculus	x	x	x	Hawaii, Atlantic
Limnodriloides rubicundus	x	x	x	Fiji, Hawaii, Atlantic
WIDELY DISTRIBUTED IN INDO-WEST PACIFIC (14 spp., 40%)				
Heronidrilus bihamis	x	x	x	Victoria (Australia), Hawaii
Heterodrilus keenani	x	x	x	Hawaii
H. claviatriatus	x	x		
Paupidrilus breviductus			x	
Pectinodrilus heronensis		x		Fiji, Aldabra
Pacifidrilus aquilinus		x	x	Hawaii
Duridrilus piger		x	x	
D. pastoralis		x	x	
Olavius clavatus	x	x		
Doliodrilus diverticulatus				Saudi Arabia
Tectidrilus arabicus				Saudi Arabia
Smithsonidrilus irregularis	x	x	x	
Limnodriloides biforis			x	
L. fraternus		x		
KNOWN ONLY FROM N.T. AND W.A. (2 spp., 6%)				
Albanidrilus wellsi	x			
Pectinodrilus multiplex	x			
KNOWN ONLY FROM N.T. (14 spp., 40 %):				
Heterodrilus rapidensis sp. n.				
Ainudrilus mediocris sp. n.				
A. brendae sp. n.				
A. piliferus sp. n.				
Albanidrilus coxensis sp. n.				
A. caswellae sp. n.				
Coralliodrilus improvisus sp. n.				
C. hanleyi sp. n.				
Bathydrilus ampliductus sp. n.				
Duridrilus darwinensis sp. n.				
Smithsonidrilus ludmillae sp. n.				
S. arduus sp. n.				
S. convexus sp. n.				
Limnodriloides lateroporus sp. n.				

Table 2. Systematic diversity of marine Tubificidae, as species frequencies (%) per subfamily, in different parts of the world: Darwin Harbour, Northern Territory (present paper); Hong Kong (Erséus 1990c, 1992b), Rottnest Island, Western Australia (Erséus 1993); and the barrier reef off Belize in the Caribbean Sea, Atlantic Ocean (Erséus 1990d). Number of species in parentheses.

Subfamily	Darwin		Hong Kong		Rottnest		Belize	
Rhyacodrilinae	25%	(9)	21%	(11)	15%	(6)	15%	(9)
Phallodrilinae	44%	(16)	37%	(19)	63%	(26)	49%	(29)
Limnodriloidinae	31%	(11)	40%	(21)	22%	(9)	32%	(19)
Tubificinae	0%	(0)	2%	(1)	0%	(0)	3%	(2)
(Total per area:	100%	(36)	100%	(52)	100%	(41)	100%	(59)

numerous stations not listed here, where Tubificidae were absent. At Rottnest Island up to ten species were found at individual stations, and few sites sampled were devoid of Tubificidae (Erséus 1993).

Nevertheless, the relatively few specimens from Darwin comprise no less than 37 species, 12 of which were each represented only by a single sexually mature individual. A cumulative species/station curve (Fig. 16) for the samples collected by the author (entering stations in chronological order; see List of Stations above) shows, after an initial very steep incline (the three first stations yielded 10 spp.), a steadily climbing curve with virtually no tendency to level out at station no. 42. Therefore, a future sampling effort in the Northern Territory (preferably including more samples from subtidal habitats) will undoubtedly yield many taxa not encountered in this study. The over 900 specimens obtained at Rottnest Island contained 41 species, just marginally greater than those found at Darwin. Thus, while tubificids are abundant at Rottnest Island, there may be a greater number of species in the Darwin Harbour area.

Prior to the Mandorah workshop, no marine Tubificidae had been recorded from the Northern Territory, but two freshwater species, *Antipodrilus magelensis* Brinkhurst, 1984, and *Ainudrilus billabongus* (Brinkhurst, 1984), were previously described from this State. Therefore, despite the evidently incomplete coverage of the local fauna, the present collection may serve as a basis for a tentative assessment of the biogeographic affinities of the marine Tubificidae of Australia's north coast (Table 1).

Over 50% (19 spp.) of all marine species found in the Darwin area are already known from other parts of the Indo-West Pacific region. The Darwin area has at least 13 tubificid species in common with Queensland, 12 in common with Hong Kong, and 10 in common with Western Australia (Table 1). Five of these are known from the Atlantic Ocean too.

Two species, *Albanidrilus wellsi* and *Pectinodrilus multiplex*, are so far exclusively known from the Northern Territory and Western Australia. The possibility that they are western, endemic, elements in the marine fauna of tropical Australia, is supported by (1) their occurrence on both the west and the south coasts of Western Australia (Erséus 1990b, 1993), and (2) the apparent replacement of *A. wellsi* in Queensland by a morphologically similar, but yet undescribed, species (Erséus 1993).

Forty percent of the marine tubificid species reported here are new to science and known only from the Northern Territory. Among them (and all other, yet undiscovered species in this State), there may of course be some that have a more limited distribution in the central Indo-West Pacific region. However, there are no records of marine Tubificidae from Indonesia, Papua-New Guinea and other adjacent areas.

A majority of the tubificid genera occurring in the tropics and subtropics are widely distributed in the world. Even if the species composition differs considerably, largely the same genera are represented in areas from opposite sides of the globe. For instance, all genera reported in this study except *Paupidrilus, Albanidrilus* and *Pacifidrilus*, are present on the Caribbean coast of Central America too (see Erséus 1990d, 1992a). Moreover, although the patterns are not clear-cut, genera or even subfamilies tend to have particular habitat preferences (Diaz and Erséus 1994). *Heterodrilus* spp. (Rhyacodrilinae) and most Phallodrilinae are common in well sorted sands, particularly those of a carbonate origin, whereas *Ainudrilus* spp. (Rhyacodrilinae) and most Limnodriloidinae prefer muddier situations, including sediments associated with seagrass or mangroves.

Differences in the faunal composition of four geographical areas compared in Table 2 are indicative of the predominant habitat types in these areas. In Darwin Harbour and Hong Kong, the intertidal and shallow water marine habitats are greatly influenced by freshwater runoff from large continents (Erséus 1984b), reflected in the moderate relative frequencies of Phallodrilinae (44 and 37%, respectively, of the total number of species known), as well as of Limnodriloidinae (31 and 40%, respectively, of all species) and Rhyacodrilinae (25 and 21 %, respectively). As a contrast, phallodrilines comprise 63%, but limnodriloidines only 22% and rhyacodrilines only 15%, of the species known from Rottnest Island, an area located well off the coast and largely dominated by coralline or limestone sediments. The barrier reef off Belize is intermediate between these two areas, with 49% Phallodrilinae. At the same time, the frequency of Limnodriloidinae (32%) is greater in Belize than at Rottnest Island, which seems correlated with the prevalence of mangrove cays and seagrass beds even at great distances from the Belizian coast (Diaz and Erséus 1994).

A striking difference between Darwin/Hong Kong and Rottnest/Belize can be noted in the number of gutless tubificids (genera *Inanidrilus* Erséus, 1979(d), and *Olavius*) recorded from these areas. In Darwin Harbour, only one gutless species (*O. clavatus*) was found, from Hong Kong none is known so far, whereas eight gutless species have been described from Rottnest Island (Erséus 1993), twelve from Belize (1990d). Gutless Tubificidae prefer reduced, fine to medium, carbonate sediments and are therefore particularly common in coral reefs. Such habitats occur off the coast of the Northern Territory also, but they remain to be studied.

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THE TEREBELLIDAE (POLYCHAETA) OF NORTHERN AUSTRALIA WITH A KEY TO ALL THE DESCRIBED SPECIES OF THE REGION.

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ABSTRACT

The terebellid fauna of northern Australia comprises 34 species of which six are new: *Amaeana yirrarn* sp. nov., *Euthelepus marchinbar* sp. nov., *Rhinothelepus buku* sp. nov., *Streblosoma maligirrima* sp. nov., *Lanicides banatawa* sp. nov., *Pista gwoyarrma* sp. nov., and *Loimia ochracea* is redescribed. Several genera (five) and many species (14) are recorded for the first time from northern Australia. Some records represent considerable range extensions. A key to the genera and species is given.

Keywords: Polychaeta, Terebellidae, taxonomy, new species, Australia, Northern Territory, keys, generic characteristics.

INTRODUCTION

The polychaete family Terebellidae has been recently revised in Australia by Hutchings and Glasby (1986a, 1987, 1988, 1990), and subsequently Hutchings (1993) described some additional species from Rottnest Island, Western Australia. Since then, additional material from northern Australia has become available for study, including material collected during the Sixth International Marine Biology Workshop held during July, 1993, and material collected by the Museum and Art Gallery of the Northern Territory and the Western Australian Museum over the past decade. As many of these species have only recently been described by Hutchings and Glasby (1986a, 1987, 1988, 1990), full descriptions and synonymies are not given below, although additional variation is described. Similarly, habitat notes are only given for material collected in northern Australia (which is here defined as from 18°S to 6°S and 122°E to 143°E) in the 'Material examined' sections. In addition, several species not represented by the material collected during the Workshop, but previously known from northern Australia, are included to give a comprehensive account of the terebellid fauna of the area. However, it must be stressed that as large areas of the northern Australian coast have not been sampled, many other species may be found in the region. Subtidal areas are particularly poorly represented.

METHODS

The following abbreviations have been used: AM, Australian Museum, Sydney; BMNH, Museum of Natural History, London; NTM, Museum and Art Gallery of the Northern Territory, Darwin; QM, Queensland Museum, Brisbane; USNM, National Museum of Natural History, Smithsonian Institution, Washington, DC; and WAM, Western Australian Museum, Perth.

Deposition of type material is indicated under 'Material examined'. Other material is listed from west to east and for some common species only a selection of the material examined is listed. In the descriptions of new species, length measurements exclude buccal tentacles and the width measurements are of anterior segments unless otherwise stated.

In: Hanley, J. R., Caswell, G., Megirian, D. and Larson, H.K. (eds). *Proceedings of the Sixth International Marine Biological Workshop. The marine flora and fauna of Darwin Harbour, Northern Territory, Australia.* Museums and Art Galleries of the Northern Territory and the Australian Marine Sciences Association: Darwin, Australia, 1997: 133–161.

KEY TO THE TEREBELLIDAE OF NORTHERN AUSTRALIA

This key is artificial for adult specimens only and does not imply phylogenetic relationships. An undescribed species of *Polycirrus* has been included.

1 a Thoracic uncini in double or alternating rows in at least some setigers; branchiae, if present, typically branched .... (Amphitritinae) 14
b Thoracic uncini, if present, in single rows or a closed loop; branchiae, if present, typically simple filaments 2

2 a Branchiae absent, tentacular membrane expanded as spherical or trilobed structure, buccal tentacles of 2 types ...(Polycirrinae) 3
b Branchiae present as simple filaments, tentacular membrane compact or expanded as an anterior projection, buccal tentacles of 1 type .... (Thelepodinae) 7

3 a Setae lacking on all segments .... *Hauchiella* sp.
b Both notosetae and neurosetae present . 4

4 a Neurosetae short-handled uncini, present on abdomen and sometimes on thorax .... (*Polycirrus*) 5
b Neurosetae long-handled spines, present only on abdomen .... (*Amaeana*) 6

5 a Notopodia from segment 2, 12 pairs, uncini from segment 14, notosetae of 2 types including some ornamented capillaries .... *P. broomensis*
b Notopodia from segment 2, 13 pairs, notosetae, of 1 type only, smooth-winged capillaries, 10 pairs .... undescribed species of *Polycirrus*

6 a 11 pairs of notopodia; achaetous region of 6-8 segments .... *A. antipoda*
b 12 pairs of notopodia; achaetous region of 10-12 segments .... *A. yirrarn* sp. nov

7 a Compact tentacular membrane 8
b Expanded tentacular membrane .... *Rhinothelepus buku* sp. nov.

8 a Notopodia beginning on segment 2 .... (*Streblosoma*) 9
b Notopodia beginning on segment 3 12

9 a Branchiae extending laterally beyond notopodia on segment 2, many branchial filaments present .... *S. acymatum*
b Branchiae not extending laterally beyond notopodia, relatively few branchial filaments 10

10 a 23-27 pairs of notopodia present ... *S. prora*
b More than 27 pairs of notopodia 11

11 a Uncini with well developed subterminal button; branchiae numbering 12 and 10 on segment 2,13 and 15 on segment 3,10 and 11 on segment 4 .. *S. maligirrima* sp. nov.
b Uncini with terminal button; branchiae numbering 6 and 7 on segment 2,3 and 4 on segment 3,1 and 3 on segment 4.. *S. dytikos*

12 a Lateral lobes present on segments 2 and 3 .... *Euthelepus marchinbar* sp. nov.
b Lateral lobes absent .... (*Thelepus*) 13

13 a Notopodia terminating half way along body, 3 pairs of branchiae, numerous filaments with large medial gap between left and right hand group of filaments .... *T. extensus*
b Notopodia continuing to pygidium, 3 pairs of branchiae, filaments extending across dorsum .... *T. robustus*

14 a Branchiae absent 15
b Branchiae present 17

15 a 16 pairs of notopodia, posterior notosetae of 2 kinds ....*Pseudoproclea australis*
b Less than 16 pairs of notopodia present, posterior notosetae of 2 kinds 16

16 a 14 pairs of notopodia, some notosetae distinctly pectinated along 1 margin, arranged in 2 tiers .... *Phisidia echuca*
b 15 pairs of notopodia, notosetae finely denticulated along one margin .... *Lanassa* sp.

17 a At least some notosetae with marginally serrated tips. 18
b Notosetae all with smooth tips 21

18 a Two pairs of branchiae, 20 pairs of notopodia .... *Amphitritides ithya*
b Three pairs of branchiae, variable number of pairs of notopodia .... (*Terebella*) 19

19 a Third pair of branchiae arising on segment 4, notopodia continuing to pygidium .... *T. pappus*
b Third pair of branchiae arising elsewhere, variable number of pairs of notopodia .. 20

20 a Third pair of branchiae arising on segment 6, body with dark pigment spots, notopodia continuing almost to pygidium .... *T. maculata*
b Third pair of branchiae arising on junction of segments 4 and 5, body without pigment spots, notopodia continuing 2/3-4/5 along body .. *T. tantabiddycreekensis*

21 a Uncini with teeth in a single row.. (*Loimia*) 22
b Uncini with main fang and crest of smaller teeth above 23

22 a Lateral lobes, 2 pairs on segments 2 and 3, peristomial lateral lobes present .... *L. ochracea*
b Lateral lobes, 2 pairs, 1 pair arising from junction of segments 2 and 3 and other on peristomium .... *L. ingens*

23 a Uncini of anterior segments short-handled 24
b Uncini of anterior segments long-handled 28

24 a Lateral lobes absent, 14-17 pairs of notopodia ....*Nicolea amnis*
b Lateral lobes present, 17 or more pairs of notopodia 25

25 a Lateral lobes present as small lappets on segments 2, 3 and 4 .... *Eupolymnia koorangia*
b Lateral lobes absent on segments 2 and 4, present on segment 3 26

26 a Peristomial lateral lobes present, 2-3 pairs branchiae of variable form, 17 pairs of notopodia. 27
b Peristomial lateral lobes absent, 2 pairs of branched branchiae, 17 pairs of notopodia .... *Lanicola lobata*

27a Segment 4 with margins extended dorsally to form a conspicuous sinus, tube with characteristic fan attached to opening .... *Lanice sinata*
b Segment 4 with margins not extended dorsally, tube with smooth margins to opening .... *Lanice bidewa*

28 a Lateral lobes present on segment 3 and sometimes on peristomium.....(*Lanicides*) 29
b Lateral lobes present on segments 2 to 4 and sometimes on peristomium... .... (*Pista*) 32

29 a Three pairs of branchiae 30
b Two pairs of branchiae .... *L. fascia*

30 a Peristomial lateral lobes triangular in shape, connected across venter, anterior uncini with poorly developed shaft. .... *L. attenuata*
b Peristomial lateral lobes present only ventrally, rectangular in shape, anterior uncini with well developed shaft 31

31 a Lateral lobes on segment 3 triangular with apex deflected dorsally ....*Lanicides banatawa* sp. nov.
b Lateral lobes on segment 3 large, semi-circular.......................... *L. tribranchiata*

32 a 2 pairs of tufted plume-shaped branchiae 33
b 2 pairs of branchiae with few dichotomous branches ....*P. violacea*

33 a Peristomium expanded to form triangular blunt lobe .... *P. curtiuncata*
b Peristomium not expanded as lateral lobe although margins may be glandular ... 34

34 a Lateral lobes on segments 2,3 and 4 all semi-circular........................ .*P. australis*
b Lateral lobes on segments 2,3 and 4 otherwise 35

35 a Lateral lobes on segment 2 rectangular, on 3 small and oval, and on 4 small with lateral extension .... *P. kimberliensis*
b Lateral lobes on segment 2 rectangular, on 3 semi-circular and on 4 small, semi-circular............... *P. gwoyarrma* sp. nov.

SYSTEMATICS

Family Terebellidae Malmgren, 1867
Subfamily Polycirrinae (Malmgren, 1866)

Polycirrinae Hessle 1917: 219; - Hutchings and Glasby 1986a: 319-320.

Diagnosis. Body often anteriorly inflated, segmentation often obscure but usually with distinct thorax and abdomen. Expanded tentacular membrane. Branchiae absent. Notopodia, if present, with setae often ornamented. Neuropodia, if present, with either avicular uncini or acicular spines. Neurosetae always arranged in single rows and neuropodial tori poorly developed. Setae, both noto- and neurosetae, may be absent.

Amaeana Hartman, 1959

Amaeana Hartman, 1959: 495; - Hutchings and Glasby 1986a: 320.

Type species: *Polycirrus trilobata* Sars, 1863, subsequent designation by Malmgren (1866).

Diagnosis. Tentacular membrane trilobed. Nine to thirteen thoracic segments. Notopodia from segment three, with smooth or barbed notosetae. Thoracic neurosetae absent, abdominal neurosetae long-shafted acicular spines.

Remarks. At least two species of *Amaeana* occur in northern Australia, including the new species which is described here. Specimens of *Amaeana* cannot be identified to species unless complete; some other fragments collected during the Workshop may belong to these two species or represent additional species or perhaps species of *Lysilla*. These two genera cannot be differentiated on the basis of anterior fragments.

Amaeana antipoda Augener, 1926

Amaea antipoda Augener, 1926: 241, fig. 17.

Amaeana antipoda - Hutchings and Glasby 1986a: 320-321, figs 1a-b; 12A; - 1990: 255.

Material examined. Northern Territory: AM W21871, AM W21872, SE Gulf of Carpentaria, 17°15.50'S 140°35.33'E, 12 m, silt, April 1994, coll. R. Hilliard; QM G211654, SE Gulf of Carpentaria, 17°15.97'S 140°37.37'E, 12 m, silt, April 1994, coll. R. Hilliard; QM G211647, SE Gulf of Carpentaria, 17°15.43'S 140°37.38'E, 11.5-12.5 m, silt, April 1994, R. Hilliard. (A selection of material examined from collections of Hilliard). NTM W3617, West Bay, Port Essington 11°16'S 132°09'E, MLW, shell debris and mud, 14 September 1985, coll. R. Hanley.

Distribution. Western Australia (Mermaid Sound, Dampier Archipelago), Northern Territory (Gulf of Carpentaria; Port Essington), Queensland (Great Barrier Reef).

Habitat. Shallow subtidal, in silty substrata.

Remarks. The material examined is in poor condition but has 11 pairs of notopodia with smooth wingless capillaries. Much of the material was damaged so that the number of achaetous segments present between the thorax and abdomen could not always be checked, although some specimens had six to eight achaetous segments, the number recorded for the species. It agrees with material previously identified by Hutchings and Glasby (1986a) as *A. antipoda* from Dampier Archipelago and the Great Barrier Reef. Ideally, additional complete material should be compared with material from the type locality (Lyttelton, New Zealand). However, Hutchings and Glasby (1986a) were unable to locate the type material. This is the first record of this species from northern Australia.

Amaeana yirrarn sp. nov.

Fig. 1A-D

Type material. HOLOTYPE - NTM W3610, Northern Territory: West Bay, Port Essington, 11°16'S 132°09'E, MLW, shell debris with mud, 14 September 1985, coll. R. Hanley. PARATYPES - NTM W3453, W side of Barrow Island, Port Essington, 11°20'S 132°13'E, intertidal, mud flats in front of mangroves, 19 September 1985, coll. R. Hanley, complete but damaged, 2.5 cm in length, 1.5 mm in width with about 90 setigers; AM W21888, West Bay, Port Essington, 11°16'S 132°09'E, MLW, shell debris with mud, 14 September 1985, coll. R. Hanley, posteriorly incomplete, 1 cm in length, 1.5 mm in width, with about 54 setigers; USNM 171055 West Bay, Port Essington 11°16'S 132°09'E, MLW, shell debris with mud, 14 September 1985, coll. R. Hanley, complete, 1.2 cm in length, 2.0 mm in width, with about 90 setigers.

Additional material. Northern Australia: NTM W3619, West Bay, Port Essington 11°16'S 132°09'E, MLW, shell debris with mud, 14 September 1985, coll. R. Hanley; NTM W3535, West Bay, Port Essington 11°16'S 132°09'E, MLW, mudflat, 14 September 1985, coll. R. Hanley; NTM W3554, West Bay, Port Essington 11°16'S 132°09'E, MLW, mud flat, 14 September 1985, coll. R. Hanley.

Description. *Holotype.* Complete individual but in two portions. Anterior portion 1 cm in length, (about 60 segments), 2.5 mm in width, abdominal portion 5 mm in length, (about 45 segments), 1.5 mm in width. Alcohol preserved specimen, reddish brown in colour.

Majority of buccal tentacle mass detached, consist of three types: narrow thin grooved tentacles, thicker tentacles of uniform width and few with expanded swollen tips. Small expanded trilobed tentacular lobe consisting of an anterior lobe and two lateral lobes, glandular and dorsal surface reticulated. Peristomium thick and glandular, swollen ventrally, not visible dorsally (Fig. 1A).

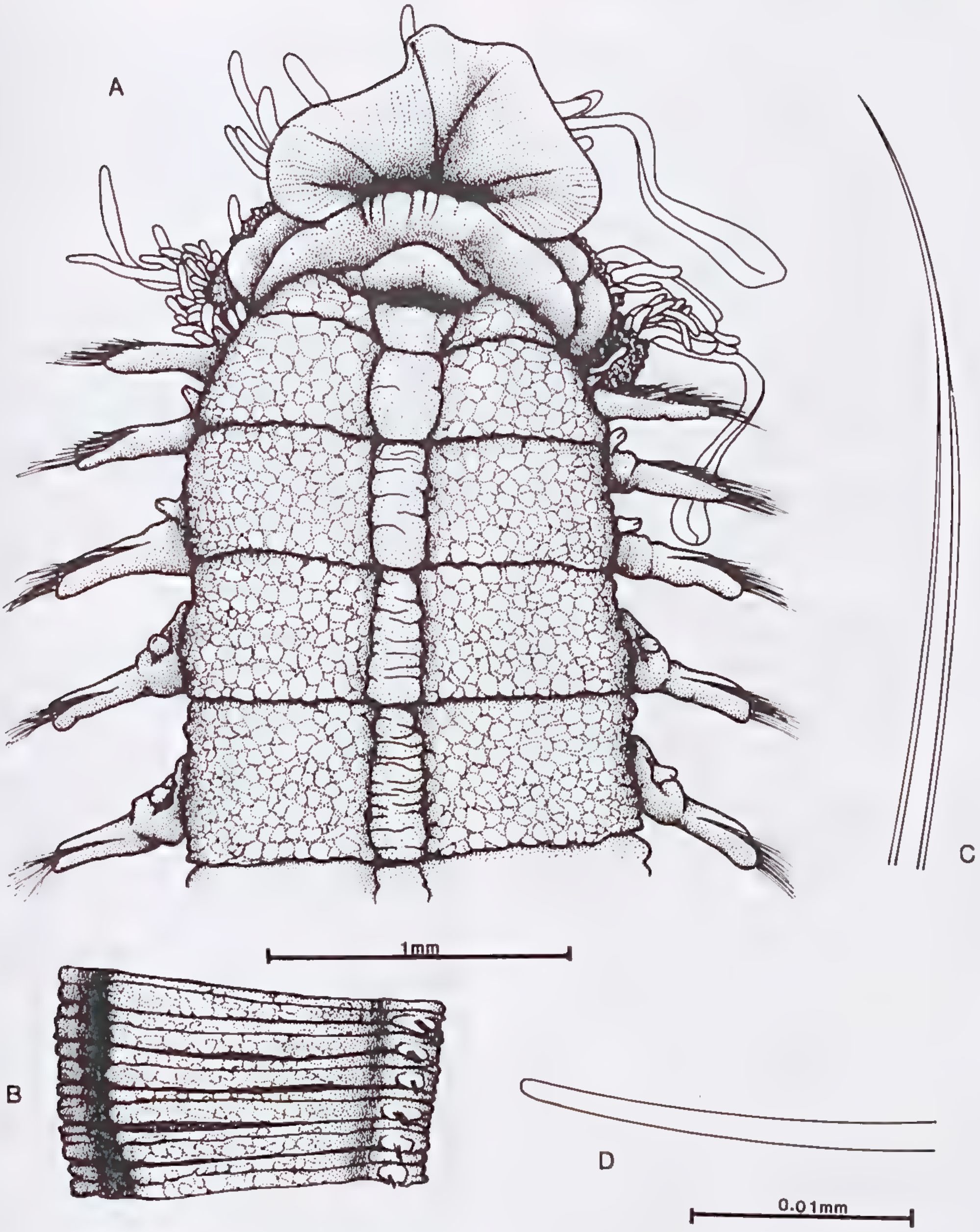

Fig. 1. *Amaeana yirrarn* sp. nov. Holotype NTM W3610; **A,** ventral view of prostomium and anterior segments; **B,** abdominal segments showing neuropodia; **C,** thoracic notoseta; **D,** abdominal neurosetal spine.

Dorsum finely tessellated and ventral surface anteriorly slightly papillated, posteriorly becoming tessellated. Entire thoracic ventral surface raised and separated mid-ventrally by glandular whitish stripe which continues onto abdomen, glandular raised ventral surface extending laterally and encircling notopodia. Abdominal ventral surface consisting of two narrow raised ridges occurring on either side of mid-ventral stripe.

Twelve pairs of notopodia from segment 3, notopodia elongate, narrow notopodia, base swollen and glandular. Notosetae number more than 20, graded in length along the notopodia, broad-bladed, narrow-winged, smooth tipped capillaries (Fig. 1C).

Nephridiopore inserted centrally on base of notopodia, extremely prominent on setigers 4-8, on other setigers represented only by small papillae. Holotype gravid female.

About 10-12 achaetous segments between last thoracic notopodial segment and first abdominal neurosetal segment; number of achaetous segments difficult to count as no clear segmentation. Abdominal neuropodia small rectangular pinnules with two to three broad, smooth, blunt-tipped spines (Fig. 1B, D).

Variation. Paratypes not gravid and the nephridiopores are poorly developed. The paratype (NTM W3453), which is complete, has posteriorly prominent acicular neurosetae which protrude from body wall.

One of the specimens (NTM W3535) listed in the 'Additional material' has 12 notopodia on one side and only 11 on the other side.

Distribution. Northern Territory (Port Essington).

Habitat. Intertidal mud flats containing shell debris in front of mangroves.

Etymology. The specific name is the word for mangrove habitats in the Iwaidja language of Cobourg Peninsula (Port Essington). Such habitats are abundant at the type locality of the species.

Remarks. Three species of *Amaeana* have previously been described from Australian waters: *A. apheles* (Hutchings, 1974) which has 9-10 pairs of notopodia and 12 achaetous segments between the thorax and abdomen, *A. trilobata* (Sars, 1863) which has 10 pairs of notopodia and an achaetous region of about three to eight segments and *A. antipoda* which has 11 pairs of notopodia and an achaetous region of six to eight segments. In contrast, *Amaeana yirrarn* sp. nov. has 12 pairs of notopodia and 10-12 achaetous segments which clearly distinguishes it from the other described species recorded from Australia. The only other species of *Amaeana* with 12 pairs of notopodia is *A. occidentalis* Hartman, 1944, described from Tomales Bay, California, which has only five to six achaetous segments between the thorax and abdomen.

Several specimens of *A. antipoda* were found during this study, and all occurred in the Gulf of Carpentaria except for the one specimen recorded from the type locality of *Amaeana yirrarn* sp. nov., at Port Essington. Although all these specimens of *A. antipoda* had only 11 pairs of notopodia, one of the specimens of the new species *A. yirrarn* had 12 on one side and 11 on the other side. This suggests that the number of notosetigerous segments is not as consistent as previous records in the literature indicates. Species of *Amaeana* have relatively few morphological characters and perhaps molecular characters may serve to better distinguish species in the genus.

Hauchiella Levinsen, 1893

Hauchiella Levinsen, 1893: 351.

Type species. *Polycirrus tribullata* McIntosh, 1869, by monotypy.

Diagnosis. Body shape typical of subfamily, except that all notopodia, neuropodia and setae lacking. Tentacular membrane expanded, with two types of tentacles. Thorax of about 10 segments, usually about 70 segments in total.

Hauchiella sp.

Material examined. Northern Territory: AM W21807, North Shell Island, Darwin Harbour, 12°29.8'S 130°53.2'E, 5-8 m, in amongst dead coral rubble, 16 July 1993, coll. P. Hutchings.

Remarks. The single anterior fragment may represent the same species as a single immature specimen collected by Hutchings and Glasby (1990) from the Kimberley region. Only two species of *Hauchiella* have been described, *H. tribullata* (McIntosh, 1869), which appears to have a world-wide distribution and occurs in Australia in Bass Strait (Hutchings and Glasby 1986a), and *H. renilla* Hutchings and Glasby, 1986a, which occurs in southern New South Wales and Queensland. Species of *Hauchiella* are particularly difficult to identify as they lack podia and all setae. These two northern Australian individuals are both immature and nephridial papillae, one of the characters used to separate the two currently described species, are not visible. Until sexually mature material is collected from northern Australia, the identity of the species must remain unknown. This is the first record of the genus from Northern Territory.

Polycirrus Grube, 1850

Polycirrus - Hutchings and Glasby 1986a: 330-332.

Type species. *Polycirrus medusa* Grube, 1850, by monotypy.

Diagnosis. Tentacular membrane trilobate, sometimes with reduced lateral lobes, with two types of buccal tentacles. Thorax with variable number of setigers, notopodia from segment 2 or 3. Neuropodia first present from segments 7-18 (setigers 6-17). Notosetae variable, including pinnate, hirsute, smooth-winged or smooth, wingless capillaries, but only one or two types of setae present in any one species.

Remarks. Among the collections of *Polycirrus* examined from northern Australia were several anterior fragments and two complete specimens of an undescribed species. Hutchings and Glasby (in prep.) are undertaking a world-wide revision of the genus; this new species will be described as part of that revision. In addition, material of *P. broomensis* was collected from several localities. Although many species of *Polycirrus* appear to live naked in the sediment, this species lives in a well developed tube.

Polycirrus broomensis Hartmann-Schröder, 1979

Polycirrus broomensis Hartmann-Schröder, 1979: 148-149, fig. 352-354. - Hutchings and Glasby 1986a: 336, fig. 7a-c; - 1990: 257.

Material examined. Western Australia: WAM 183-86, Cape Lambert, 22°36'S 117°10'E; NTM W4601, East Roebuck Bay, Broome, 17°59'S 122°15'E, LWS, sandy tidal flat, 19 March 1987, coll. R. Hanley; NTM W7010, Roebuck Bay, Broome, 17°59'S 122°15'E, LWS, mudflat, 29 August 1980, coll. R. Hanley. Northern Territory: NTM W4953, Ludmilla Creek, Darwin, 12°24.8'S 130°50.2'E, MLW, mudbank, 4 March 1988, coll. R. Hanley; NTM W4499, Ludmilla Creek, Darwin, 12°24.8'S 130°50.2'E, LWS, 16 February 1987, coll. R. Hanley; NTM W3428, Victoria Settlement, Port Essington, 11°16'S 132°09'E, LWS, sandy beach with silt, 18 September 1985, coll. R. Hanley.

Distribution. Western Australia (Cape Lambert; Broome), Northern Territory (Darwin Harbour; Port Essington).

Habitat. Intertidal sand and mud flats.

Remarks. Several specimens were found in their tubes which are made of cemented sand grains and are fairly rigid. The species also occurs at Cape Lambert, Western Australia which extends its southern distribution.

Subfamily Thelepodinae Hessle, 1917

Thelepodinae Hessle, 1917: 144-149. - Holthe 1986a: 139; - 1986b: 71 (*nomen correctum*).

Thelepinae Hessle, 1917: 144-149.

Diagnosis. Thorax and abdomen usually not well demarcated. Tentacular membrane compact or expanded. Branchiae usually present as simple filaments. Ventral pads well developed. Notosetae simple capillaries either smooth or with serrated tips. Neurosetae avicular uncini, arranged in single, sometimes irregularly folded rows or loops.

Remarks. The subfamily is well represented in northern Australia with four genera and eight species.

Euthelepus McIntosh, 1885

Euthelepus - Hutchings and Glasby 1986b: 105.

Type species. *Euthelepus setubalensis* McIntosh, 1885, by original designation.

Diagnosis. Tentacular membrane compact, with numerous grooved buccal tentacles. Three pairs of long thick branchiae, relatively few filaments present on segments 2, 3 and 4. Lateral lobes present on segments 2-3 and sometimes 4. Notopodia present from segment 3 and continuing for variable number of segments. Notosetae either all smooth-tipped or mixture of smooth-tipped and serrated types. Neuropodia present from segment 5 (setiger 3) continuing to pygidium. Uncini with dorsal attachment button.

Euthelepus marchinbar sp. nov.

Fig. 2A-E

Type material. HOLOTYPE - NTM W9547, Northern Territory: Marchinbar Island 11°15'S 136°38'E, 14 November 1990, coll. R. Hanley. PARATYPE - AM W21889, Northern Territory, Marchinbar Island, 11°15'S 136°38'E, 14 November 1990, coll. R. Hanley, posteriorly incomplete, 1.6 cm in length, 1.5 mm in width, with about 45 segments.

Additional material. Western Australia: NTM W4342, Gantheaume Point, Broome, 17°58'S 122°14'E, LWS, under rock slabs in silt, 15 March 1987, coll. R. Hanley; NTM W4343, Gantheaume Point, Broome, 17°58'S 122°14'E, LWS, under rock slabs in silt, 15 March 1987, coll. R. Hanley.

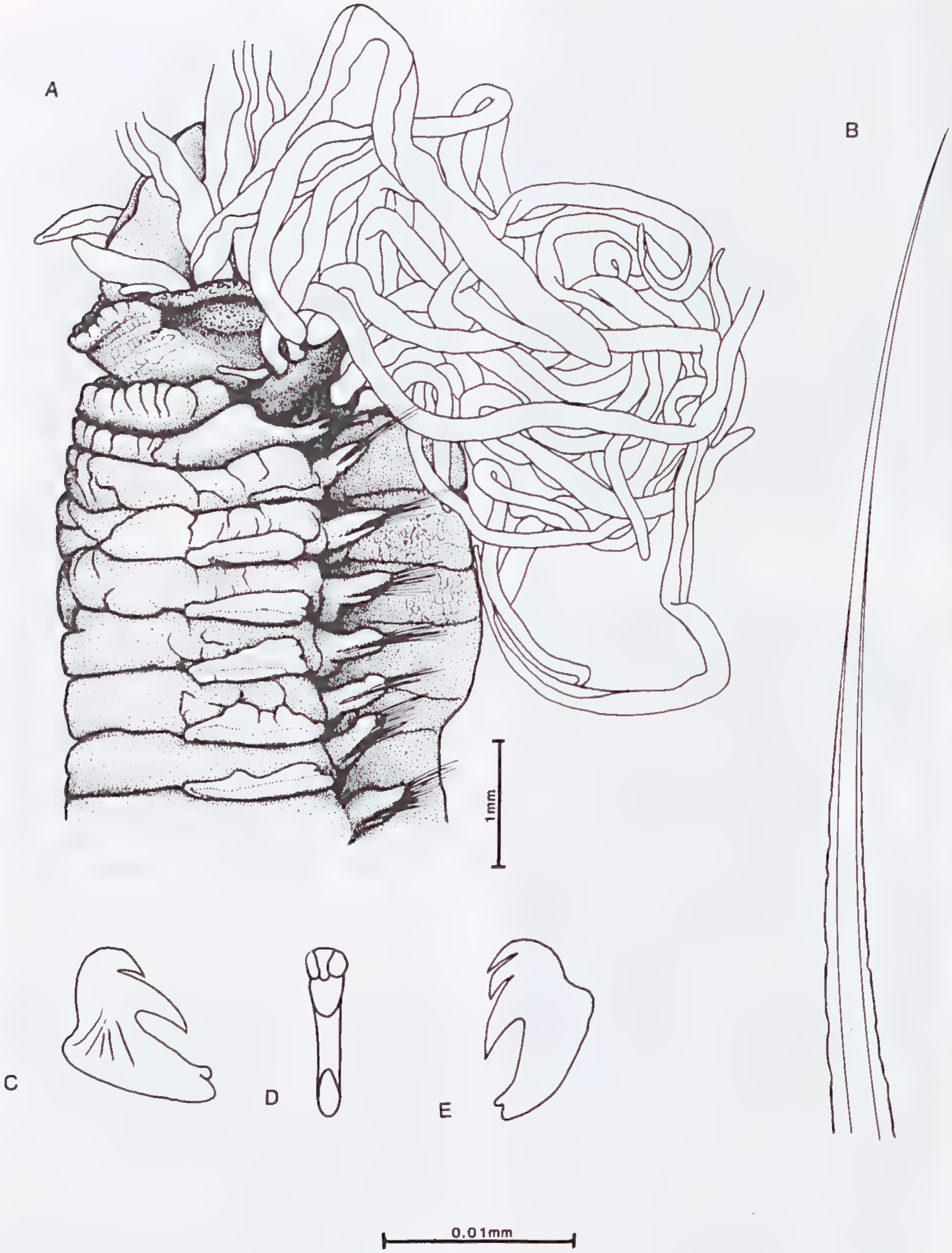

Fig. 2. *Euthelepus marchinbar* sp. nov. Holotype NTM W9547; **A**, lateral view of prostomium and anterior segments; **B**, thoracic notoseta from setiger 12; vertical striations not shown; **C**, lateral view of thoracic uncinus from setiger 12; **D**, head on view of same thoracic uncinus; **E**, lateral view of abdominal uncinus from setiger 30.

Description. *Holotype.* Posteriorly incomplete, alcohol preserved material, pale beige in colour, 3.5 cm in length, 4 mm in width for about 58 segments.

Tentacular membrane short and compact with numerous grooved buccal tentacles varying in thickness. Upper lip rectangular in shape with straight glandular margins. Peristomium simple glandular ring, with many eye spots extending across dorsum in continuous elongate line.

Three pairs of branchiae on segments 2, 3 and 4. Branchiae simple, long filaments extending for at least six to seven setigers when fully extended, arising from slightly raised glandular area on anterior margin of each segment (Fig. 2A); small medial gap separating right and left hand group of filaments. Segment 2 with eight and eight filaments extending slightly laterally, segment 3 with seven and nine and segment 4 with six and six. Filaments arranged in single transverse line on each segment (Fig. 2A).

Notopodia beginning on segment 3 and continue for 34 segments, podia elongate, rectangular, glandular, with rounded margins and posterior margin longer than anterior one. Notopodia of setiger 1 (segment 3) markedly smaller than subsequent ones. Notosetae numerous, graded in length within fascicle, setae broad-bladed with vertical striations, narrow-winged with extended narrow, smooth tips, some setae with wings slightly twisted (Fig. 2B).

Neuropodia beginning on segment 4 (setiger 2) and present on all subsequent segments. Thoracic tori gradually becoming slightly erect and by setiger 16, tori shorter and more erect; beyond notopodial segments, neuropodia prominent. Anterior uncini arranged in single row, posterior ones arranged in shallow 'C' shape. Anterior uncini avicular with prominent dorsal button (Fig. 2C-D) and dental formula of MF:3; uncini within a torus having same dental formula. Uncini from setiger 30 similar in lateral view to thoracic uncini (Fig. 2E), but additional row of teeth present; dental formula varying within single row from MF:3:2 to MF:3:3.

Ventral surface initially extremely glandular but smooth, ventral pads developed; by setiger 11 ventral surface strongly rugose. Thoracic notopodia and neuropodia arranged on glandular area contiguous with ventral glandular area.

Lateral lobes present on segments 2 and 3, small, rectangular. Segment 4 with slightly projecting, elevated anterior margins.

Nephridial papillae not visible.

Variation. The paratype has 37 pairs of notosetae.

Distribution. Western Australia (Broome), Northern Territory (Marchinbar Island, type locality).

Habitat. Intertidal in muddy substrata where some solid substrate is presumably available for the tubes to be attached, although no tubes were present with the specimens.

Etymology. The specific name refers to the type locality of this species.

Remarks. Hutchings and Glasby (1986b) revised the genus *Euthelepus* and provided a key to the species, and described the three valid species *E. setubalensis* McIntosh, 1885, *E. kinsemboensis* Augener, 1918, and *E. serratus* Hutchings and Glasby, 1986b, of which only *E. serratus* occurs in Australia. *Euthelepus marchinbar* sp. nov. can be easily distinguished from these species by the presence of smooth-tipped notosetae only, whereas both *E. kinsemboensis* and *E. serratus* have serrated notosetae. *Euthelepus setubalensis* has smooth notosetae like *E. marchinbar* sp. nov., but has poorly developed lateral lobes and far fewer branchial filaments, although the number of branchial filaments present may be size dependent.

The paratype of *Euthelepus marchinbar* sp. nov. has no coelomic gametes visible whereas the holotype has a few sperm in the form of rosettes of spermatids within the coelom.

Rhinothelepus Hutchings, 1974

Rhinothelepus Hutchings, 1974: 192-193, fig. 6a-b.

Type species. *Rhinothelepus lobatus* Hutchings, 1974, by original designation.

Diagnosis. Elongated tentacular lobe and numerous simple branchial filaments present on segments 2 and 3. Smooth-tipped notosetae, notopodia beginning on segment 3 and continuing for 15 segments. Neuropodia beginning on segment 8 (setiger 6) and continuing onto abdomen. Uncini short-based with subterminal dorsal button. Lateral lobes absent.

Rhinothelepus buku sp. nov.

Fig. 3A-D

Type material. HOLOTYPE - NTM W9549, Northern Territory, Melville Bay, Gove, 12°11'45"S 136°41'17"E, 8 m, St. D6 WA, 22 March 1992, coll. R. Hanley *et al.* PARATYPE - NTM W9550, Melville Bay, Gove, 12°11'45"S

136°41'17"E, 8 m, St. D6 WA, 22 March 1992, coll. R. Hanley *et al.*, posteriorly incomplete, 5 mm in length, 1.0 mm in width, with about 21 segments.

Description. *Holotype*. Posteriorly incomplete, 0.7 cm in length, 2 mm in width for 21 segments, alcohol preserved material pale cream in colour.

Tentacular membrane expanded to form elongate tentacular lobe with crenulated margins, ventral lip also expanded to form tongue-like projection with convoluted margins. Two groups of discrete dorso-lateral peristomial eye spots. Few grooved buccal tentacles remaining. Peristomium simple glandular ring only visible dorsally, ventrally hidden by ventral pads (Fig. 3A).

Branchiae present on segments 2 and 3, consisting of simple, short filaments arising from body wall, arranged with distinct medial gap, not extending laterally. About 12 branchial filaments on each side of both segments 2 and 3.

Notopodia beginning on segment 3 and continuing for 15 segments, podia narrow and elongate. Notosetae, about 10+ within a fascicle, consisting of 2 tiers, broad-bladed, with vertical striations, narrow-winged, with smooth, elongated tips (Fig. 3B).

Neuropodia beginning on segment 8 (setiger 6) on one side and on setiger 7 on other side, continuing to pygidium. Neuropodial tori initially short, then rapidly increasing in length on the thorax, subsequently decreasing in length again on abdomen.

Uncini small, avicular in shape with pronounced dorsal button, thoracic uncini with dental formula MF:7:6-8:∞ (Fig. 3C), abdominal uncini smaller than thoracic with about 30+ in a row, dental formula MF:6-7:∞, (Fig. 3D), abdominal uncini arranged in 'C' shaped row.

Lateral lobes absent. Ventral surface of anterior 4 segments glandular, forming ventral rings, segment 5 with ventral surface extremely glandular and with anterior margins elevated forming a partial collar. Subsequent thoracic segments lacking distinct ventral pads, instead with entire ventral surface glandular; posteriorly progressively reduced forming mid-ventral groove which continues along abdomen to pygidium.

Nephridial papillae not visible.

Variation. The paratype has neuropodia beginning on setiger 6 on both sides. This arrangement has been shown in Figure 3A, even though, as indicated above, the holotype is not symmetrical.

Distribution. Species known only from the type locality, Melville Bay, Gove, northern Australia.

Habitat. Shallow subtidal, but no substrata data are available. All material collected during the wet season.

Etymology. The specific name is the word for a hill or mountain in the various Yolgnu Matha language dialect groups around Melville Bay, the type locality, and refers to the prominent subterminal dorsal button on the uncini.

Remarks. The genus *Rhinothelepus* contains three previously described species, two occur-

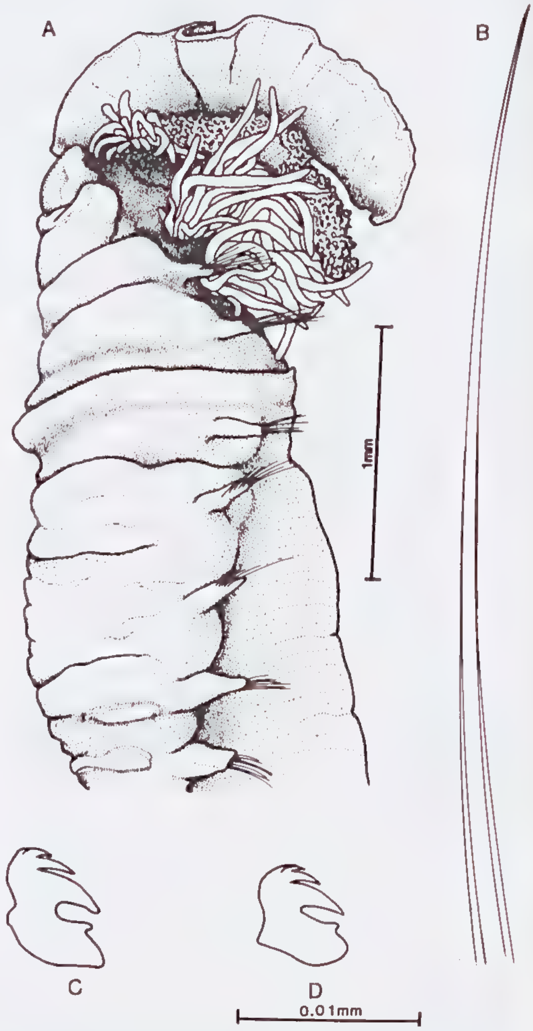

Fig. 3. *Rhinothelepus buku* sp. nov. Holotype NTM W9549: **A,** lateral view of prostomium and anterior segments; **B,** thoracic notoseta from setiger 12; **C,** lateral view of thoracic uncinus from setiger 12; **D,** lateral view of abdominal uncinus from third abdominal segment.

ring in eastern Australian waters, *R. lobatus* Hutchings, 1974, and *R. macer* Hutchings, 1977 and one species from Hong Kong waters, *R. occabus* Hutchings, 1990. *Rhinothelepus buku* sp. nov. can be distinguished from *R. occabus* as the first two pairs of notopodia are not displaced laterally and in which there is a distinct medial gap between the left and the right group of branchial filaments. *Rhinothelepus lobatus* has a dorsomedial ridge between the prostomium and the peristomium which is lacking in *R. buku* sp. nov., and *R. macer* has the first two pairs of notopodia displaced laterally whereas they are displaced slightly dorsally in the new species. Finally, the dorsal button appears to be far more prominent in *R. buku* sp. nov., than in previously described species.

Neither the holotype or paratype contains visible coelomic gametes.

Streblosoma Sars, 1872

Streblosoma - Holthe 1986a: 142; - Hutchings and Glasby 1987: 222.

Type species. *Grymaea bairdi* Malmgren, 1866, subsequent designation by Sars (1872).

Diagnosis. Tentacular membrane short and compact, numerous buccal tentacles. Lateral lobes absent. Zero to three pairs of simple, unbranched branchial filaments. Notopodia beginning on segment 2 (first branchiferous segment) and continuing for variable number of segments, smooth-tipped capillary notosetae. Neurosetae from segment 5 (setiger 4) continuing to pygidium; avicular uncini, typically arranged in single rows throughout (occasionally arranged in incomplete loop).

Remarks. At least five species of *Streblosoma* occur in northern Australia, three previously described, a new species described here and another species which is only known from a fragment (Hutchings and Glasby 1990). Additional material is needed before that species can be described.

Streblosoma acymatum Hutchings and Rainer, 1979

Streblosoma acymatum Hutchings and Rainer, 1979: 787-789, fig. 10a-b.

Material examined. Western Australia: WAM 193-86, Riddel Point, Broome, 18°00'S 122°12'E, 19 July 1982, coll. L. Marsh and S. Slack-Smith.

Distribution. Western Australia (Dampier Archipelago; Broome), Northern Territory (Numbalwar; Gove), Queensland (Calliope River) and New South Wales (Sydney).

Habitat. Intertidal.

Remarks. Hutchings and Glasby (1987) had previously reported the species from both Numbulwar and Gove, in the Northern Territory. This is the first record of the species from NW Australia and extends the known range from Sydney around to NW Australia.

Streblosoma dytikos Hutchings and Glasby, 1990

Streblosoma dytikos Hutchings and Glasby, 1990: 259-260, fig. 1a-e.

Material examined. None.

Distribution. Western Australia (King George Sound to the Kimberley region).

Habitat. Intertidal to shallow subtidal habitats, in among crevices.

Remarks. The type locality of this species is King George Sound in Western Australia, although it is also known from the Kimberley region. To date, the species has not been recorded from the Northern Territory, but it seems likely to occur there.

Streblosoma maligirrima sp. nov.

Fig. 4A-G

Type material. HOLOTYPE - NTM W4795, Northern Territory, Shell Island, East Arm, Darwin Harbour, 12°29.8'S 130°53.2'E, LW, rocky intertidal, 18 March 1988, coll. A. Mussig. PARATYPES - NTM W4801, Shell Island, East Arm, Darwin Harbour, 12°29.8'S 130°53.2'E, LW, rocky intertidal, 18 March 1988, coll. A. Mussig, posteriorly incomplete, 2.5 cm in length, 1.5 mm in width with 63 segments; AM W21890, Shell Island, East Arm, Darwin Harbour, 12°29.8'S 130°53.2'E, LW, rocky intertidal, 18 March 1988, coll. A. Mussig, posteriorly incomplete, 2 cm in length, 1.3 mm in width with 55 segments; USNM 171056, Shell Island, East Arm, Darwin Harbour, 12°29.8'S 130°53.2'E, LW, rocky intertidal, 18 March 1988, coll. Mussig, 3 specimens all posteriorly incomplete, 2 cm in length, 1.5 mm in width with 63 segments, 1 cm in length, 1.5 mm in width with 38 segments, 1.2 cm in length, 1.5 mm in width with 39 segments; BMNH ZB 1994.5824, Shell Island, East Arm, Darwin Harbour, 12°29.8'S 130°53.2'E, LW, rocky intertidal, 18 March 1988, coll. A. Mussig, posteriorly incomplete, 3.5 cm in length, 1.5 mm in width with 60 segments.

Additional material. Northern Territory: AM W21891, AM W21892, Lee Point, Darwin Harbour, 12°20'S 130°53.8'E, intertidal, crevice fauna, 19 July 1993, coll. P. Hutchings; NTM W4843, East Arm boat ramp, Darwin Harbour, 12°27'S 130°51.08'E, LWS, in front of mangroves, 1 June 1987, coll. R. Hanley; NTM W4205, Port Essington, 11°16'S 132°09'E, LWS, sandy beach, 18 September 1985, coll. R. Hanley.

Description. *Holotype*. Alcohol preserved specimen pale cream in colour, in three pieces, anterior fragment 3 cm in length, 1.5 mm in width for 45 setigers, mid fragment 1 cm in length, 1.5 mm in width for 14 setigers and posterior fragment 2 cm in length, 1.5 mm in width for 26 setigers.

Tentacular membrane short and compact with glandular lower lip, buccal tentacles largely missing on holotype but present on paratypes, numerous, grooved. Peristomium glandular with margins somewhat less glandular and slightly convoluted, peristomial eye spots present in two discrete lateral groups (Fig. 4A).

Segments 2, 3 and 4 with numerous simple branchial filaments arising from slightly swollen body wall, forming slight branchial ridge. Segment 2 with 12 and 10 filaments, segment 3 with 13 and 15 and segment 4 with 10 and 11, distinct medial gap separating left and right hand group of filaments. Filaments not extending laterally beyond line of notopodia (Fig. 4A).

Notopodia from segment 2, continuing for large number of segments, at least 85 for the

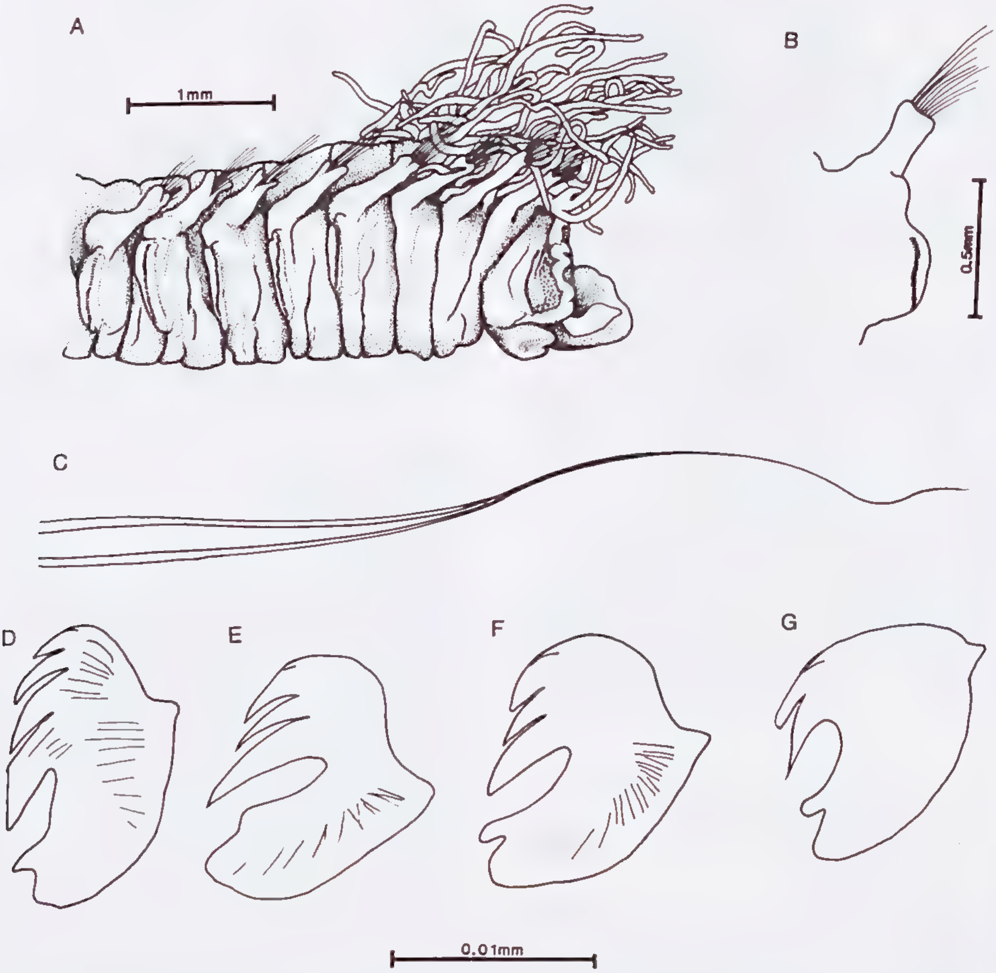

Fig. 4. *Streblosoma maligirrima* sp. nov. Holotype NTM W4795: **A,** lateral view of prostomium and anterior segments; **B,** parapodium of setiger 47, right side viewed posteriorly; **C,** thoracic notoseta from setiger 12, vertical striations not shown; **D, E, F,** lateral view of thoracic uncini from setiger 12; **G,** lateral view of abdominal uncinus mid abdominal segment.

three fragments; notopodia elongate rectangular, distally bilobed, both lobes similar in length. No type material complete, so number of pairs of notopodia unknown. Notosetae arranged in a shallow arc between two lobes, arranged in two tiers, consisting of nine and ten setae on setiger 12; setae narrow-winged, broad-bladed with vertical striations, extremely long tapering tips with transverse striations (Fig. 4C).

Neuropodia from segment 5, tori elongate, by mid thorax tori glandular, posterior thoracic tori becoming slightly erect and strongly erect on abdomen (Fig. 4B). Thoracic neuropodia and notopodia forming single glandular structure. Uncini arranged in single rows throughout; uncini avicular with well developed sub terminal dorsal button, thoracic uncini with dental formula MF:2:3:2:∞, (Fig. 4D-F), abdominal uncini similar in shape (Fig. 4G) and with dental formula MF:3-4:5:∞. Shape and orientation of the dorsal button varies between thoracic and abdominal uncini and within torus.

Ventral pads absent, instead, entire venter of thorax glandular. Dorsum smooth.

Tubiculous with tube made of small gravel fragments.

Distribution. Northern Territory (Shell Island, East Arm, Darwin Harbour; Port Essington).

Habitat. Rocky intertidal.

Etymology. The specific name is one of the words for a spear used by the Larrakia people of Darwin Harbour, the type locality, and refers to the extremely long capillary notosetae present in the species.

Remarks. The holotype of *Streblosoma maligirrima* sp. nov. has spermatogonia arranged in rosettes in the coelom.

Hutchings and Glasby (1990) provided a detailed table listing diagnostic features of all species of *Streblosoma* recorded from South East Asia and Australia. Using this table, *Streblosoma maligirrima* sp. nov. can be easily distinguished from all other described species from the area. The new species most closely resembles *S. amboinense* Caullery, 1944, but differs in that the dorsal button of the uncini is sub-terminal although the shape and orientation varies within an individual, fewer branchial filaments are present, a branchial ridge is present. The fine extended tips of the notosetae are also unusual for species of *Streblosoma*.

Streblosoma prora
Hutchings and Glasby, 1987

Streblosoma prora Hutchings and Glasby, 1987: 225-226, figs 3a, 4f-l.

Material examined. Northern Territory: NTM W16000, Melville Bay, Gove, 12°11'45"S 136°41'17"E, St A12 WA, 12.3 m, sandy grey mud, seagrasses, 19 March 1992, coll. R. Hanley *et al.*

Distribution. Northern Australia (Gove), Queensland (Halifax Bay).

Habitat. Shallow subtidal sandy mud substrata with seagrasses.

Remarks. This species was previously only known from Halifax Bay, just north of Townsville. The two specimens from Gove have 30 pairs of notopodia whereas the original material has between 23 and 27 pairs of notopodia. This slightly greater number of notopodia is not regarded as significant. The Gove material has the following number of branchial filaments, (numbers given for both right and left hand group for both individuals) segment 2, 6,10 and 5,7; segment 3: 3,3 and 4,7; segment 4: 8,7 and 4,6. These numbers are within the lower range of branchial filaments previously reported.

Thelepus Leuckart, 1849

Thelepus - Hutchings and Glasby, 1987: 226.

Type species. *Amphitrite cincinnatus* Fabricius, 1780, designated by monotypy.

Diagnosis. Tentacular membrane short, compact, collar-like, usually with numerous eye spots. Branchiae consisting of numerous simple filaments arranged in transverse rows, typically on segments 2-4, but sometimes only on segment 2; occasionally branchiae completely absent. Notopodia from segment 3 (second branchiferous segment), extending for variable number of segments, notosetae smooth-tipped capillaries. Neuropodia from segment 5 (setiger 3), continuing for variable number of segments; neurosetae avicular uncini with prow below attachment button variously developed.

Remarks. One species, *Thelepus robustus,* is extremely common and appears to occur throughout the area. At least one other species of *Thelepus* is present but currently it is only known from fragments and therefore is not described here. Two juvenile specimens of *Thelepus* were examined from Ashmore Reef and probably represent an undescribed species. Only juveniles are currently available, so the material (NTM W4326, W4317) has not been described as the diagnostic characters of the Thelepodinae may change as the animal matures.

Thelepus extensus Hutchings and Glasby, 1987

Thelepus extensus Hutchings and Glasby, 1987: 233-236, figs 8A, 9A-E, 10; - 1990: 263-264.

Material examined. Western Australia: NTM W4360, Gantheaume Point, Broome, 17°58'S 122°14'E, LWS, rock slab on silt, 15 March 1987, coll. R. Hanley. Northern Territory: NTM W3938, East Point, Fannie Bay, Darwin Harbour, 12°24.6'S 30°39.95'E, MLW, rocks embedded in mud, 11 March 1986, coll. R. Hanley.

Distribution. Western Australia (widespread), Northern Territory (Darwin Harbour), and around the south coast to southern Queensland.

Habitat. Intertidal under boulders or in crevices.

Remarks. The material examined represents a new record for the Northern Territory and agrees well with the type material and description. Previously the species was known to occur only as far north as Dongara on the Western Australian coast, although it appears to be more common in southern waters.

Thelepus robustus (Grube 1878)

Thelepus robustus - Hutchings and Glasby 1987: 241-242, figs. 8B, 11B; - 1990: 264.

Material examined. (A selection). Western Australia: WAM 185-86 Gantheaume Point, Broome, 17°58'S 122°14'E, intertidal, 31 July 1982; NTM W4542, Gantheaume Point, Broome, 17°58'S 122°14'E, LWS, under rock slab, 15 March 1987, coll. R. Hanley; NTM W4657, Broome jetty, 17°58'S 122°14'E, LWS, rocky reef and rubble, 20 March 1987, coll. R. Hanley; NTM W7012, Roebuck Bay, Broome, 17°59'S 122°15'E, LWS, rocky reef, 29 August 1991, coll. R. Hanley. Northern Territory: AM W21842, East Point, Darwin Harbour, 12°24.6'S 30°39.95'E, 10 m, coral rubble and algal washings, 17 July 1993, coll. P. Hutchings; AM W21845, Dudley Point, Darwin Harbour, 12°25.15'S 130°40'E, 8 m, coral rubble and algal washings, 1993, coll. P. Hutchings; AM W21838, Mandorah, Darwin Harbour, 12°26.9'S 130°45.6'E, intertidal, muddy sand with occasional boulders, 6 July 1993, coll. P. Hutchings; NTM W3949, Ludmilla Creek, Darwin Harbour, 12°24.8'S 130°50.2'E, MLW, sandy flats, 5 June 1986, coll. R. Hanley; NTM W135, Sandy Island, 11°07'S 132°17.5'E, 14 m, muddy substrate, 2 May 1982, coll. R. Hanley; AM W21834, Old Man Rock, Darwin Harbour, 12°29'9'S 130°54.2'E, 7 m, coral rubble, 17 July 1993, coll. P. Hutchings; NTM W4206, Port Essington, 11°16'S 132°09'E, LWS, sandy beach, 18 September 1985, coll. R. Hanley: NTM W 1769, Annesley Point 11°24'S 122°51'E, LWS, in mangroves, 19 June 1984, coll. R. Hanley; NTM W3635, Mangrove Point, Port Essington, 11°16'S 132°09'E, LWS, rocky reef, 15 September 1985, coll. R. Hanley.

Distribution. Subtropical, Western Australia, Northern Territory, Queensland.

Habitat. Intertidal to shallow subtidal, in sand to muddy substrata, and inshore fringing coral reefs, may occur in dense colonies on the undersurface of boulders. Tubiculous species with robust tubes made of small pieces of shell fragments and gravel firmly cemented to the rocks.

Remarks. The material examined agrees well with the revised description and material examined by Hutchings and Glasby (1987). This is the first record of the species from the Northern Territory although it was previously known from the Kimberley region.

Subfamily Amphitritinae Malmgren, 1866

Diagnosis. Tentacular membrane (= prostomium) compact. Branchiae present or absent, none to three pairs, typically branched or tufted. Lateral lobes present or absent on anterior segments 2-4. Peristomium may be expanded to form lobe. Notopodia present for variable number of segments; notosetae smooth or serrated. Neuropodia present on large number of segments; neurosetae avicular uncini, short or long-handled, initially arranged in single rows but subsequently arranged in double rows on thoracic segments and then reverting to single rows again on posterior segments. Distinct ventral glandular pads present on anterior thoracic segments, but not always segmentally demarcated.

Amphitritides Augener, 1922

Amphitritides Augener, 1922: 47. - Hutchings and Glasby 1988: 6.

Type species. *Terebella gracilis* Grube, 1860, by original designation.

Diagnosis. Branchiae two pairs, on segments 2 and 3, stalked. Lateral lobes absent. Notopodia from segment 4, continuing for variable number of segments; notosetae distally serrated. Neuropodia with uncini from segment 5 (setiger 2), arranged in double rows, face to face on some thoracic and abdominal segments.

Amphitritides ithya Hutchings and Glasby, 1988

Amphitritides ithya Hutchings and Glasby, 1988: 8-10, fig. 3a-d; - 1990: 265-266.

Material examined. (A selection). Northern Territory: AM W21816, Channel Island, Darwin Harbour, 12°32.85'S 130°51.8'E, LWS, crevice fauna, 20 July 1993, coll. P. Hutchings; NTM W3789, Channel Island, Darwin Harbour, 12°32.85'S 130°51.8'E, LW, rocky reef, muddy substrate, 24 February 1986, coll. R. Hanley; NTM W4763, Lee Point, Darwin Harbour, 12°20'S 130°53.8'E, LWS, rocky reef with coral, 10 September 1987, coll. R. Hanley; AM W21825, Dudley Point, Darwin Harbour, 12°24.9'S 130°49'E, 7-8 m, dead coral rubble, 18 July 1993, coll. P. Hutchings; AM W21818, North Shell Island, Darwin Harbour, 12°29.8'S 130°53.2'E, 5-8 m, dead coral rubble, 16 July 1993, coll. P. Hutchings.

Distribution. Western Australia (Albany; Kimberley region), Northern Territory (Darwin Harbour), Queensland (Port Denison; Gulf of Carpentaria).

Habitat. Occurs as crevice fauna, in shallow subtidal and intertidal areas.

Remarks. The material examined agrees well with the original material and description and the additional comments of Hutchings and Glasby (1990) regarding the increased range of notopodial segments (19-24). The species had previously been reported from northern Australia. This study has shown that is a common species in the Darwin region, although not previously recorded from the Northern Territory.

Eupolymnia Verrill, 1900

Eupolymnia - Hutchings and Glasby, 1988: 12-13.

Type species. *Amphitrite nesidensis* delle Chiaje, 1828, subsequent designation by Hartman, 1959.

Diagnosis. Branchiae, three pairs on segments 2,3 and 4, branched. Lateral lobes present on segments 2,3 and 4. Notopodia from segment 4, 17 pairs; smooth-tipped notosetae. Neuropodia present from segment 5 (setiger 2).

Eupolymnia koorangia Hutchings and Glasby, 1988

Eupolymnia koorangia Hutchings and Glasby, 1988: 13-15, fig. 5a-c; - 1990: 266.

Material examined. (A selection). Western Australia: NTM W6826, Cockatoo Island, 16°06'S 123°37'E, MLW, coral rubble in mud, 25 August 1991, coll. R. Hanley; NTM W5288, Cassini Island, 13°57'S 125°38'E, LW, rocky intertidal, 11 October 1988, coll. R. Hanley. Northern Territory: NTM W5371, Channel Island, Darwin Harbour, 12°32.85'S 130°51.8'E, LWS, reef flat, 26 October 1988, coll. R. Hanley; NTM W4233, Weed Reef, Darwin Harbour, 12°30'S 129°48'E, 11 m, rocky reef, 8 June 1984, coll. R. Hanley; AM W21814, Weed Reef, Darwin Harbour, 12°29.7'S 130°53.2'E, 2-3 m, dead coral rubble, 10 July 1993, coll. P. Hutchings; AM W21863, East Point, Darwin Harbour, 12°24.6'S 130°39.95'E, 7-10 m, dead coral rubble, 17 July 1993, coll. P. Hutchings; AM W21857, Lee Point, Darwin Harbour 12°20'S 130°53.8'E, 3 m, dead coral rubble, 11 July 1993, coll. P. Hutchings; NTM W16001, Drimmie Arm, Gove, 12°11'45"S 136°41'17"E, St. C3 WA, 15 m, seagrass, 12 July 1991, coll. R. Hanley *et al.*

Distribution. Recorded from all around Australia.

Habitat. Intertidal to shallow subtidal, associated with coral rubble and algae, and in the Gove area with seagrasses.

Remarks. The present material examined agrees well with the original material and description of this species, which occurs throughout Australia. This is the first record of the species from the Northern Territory, extending its distribution to around Australia.

Lanassa Malmgren, 1866

Lanassa Malmgren, 1866: 385-386. - Hutchings and Glasby 1988: 15.

Type species. *Lanassa nordenskioldi* Malmgren, 1866, by original designation.

Diagnosis. Branchiae absent. Lateral lobes sometimes present. Ventral glandular pads well developed. Notopodia beginning on segment 4 and present on following 14 segments (15 pairs of notopodia). Notosetae of two types including finely denticulated capillaries. Neuropodia from segment 5 (setiger 2), initially arranged in single rows, but subsequently some neuropodia with uncini arranged in double rows and posteriorly uncini arranged in single rows again.

Lanassa sp.

Material examined. None.

Remarks. An incomplete specimen of *Lanassa* was found in the Kimberley region (Hutchings and Glasby 1990) and no additional material was found during this study.

Lanice Malmgren, 1866

Lanice - Hutchings and Glasby 1988: 17-18.

Type species. *Nereis conchilega* Pallas, 1766, by monotypy.

Diagnosis. Branchiae, three pairs, present on segments 2,3 and 4; dichotomously branched. Lateral lobes present on peristomium and segment 3. Notopodia present from segment 4, continuing for 17 segments; notosetae smooth-tipped capillaries. Neuropodia present from segment 5 (setiger 2); neurosetae initially arranged in single rows, subsequently in double rows on posterior thorax, and again in single rows on abdominal tori. Tube with or without branched, finely-meshed fan attached to opening.

Lanice bidewa Hutchings and Glasby, 1988

Lanice bidewa Hutchings and Glasby, 1988: 18-20, figs 7a-c; - 1990: 267-268.

Material examined. Western Australia: NTM W14028, Town Wharf, Broome, 17°59'S 122°11'E, 16 March 1987, coll. R. Hanley; NTM W14027, Broome jetty, 17°59'S 122°11'E, 20 March 1987, coll. R. Hanley. Northern Territory: NTM W6135, Gugari Rip, 11°34'S 136°21.4'E, 21 m, rocky reef, 13 November 1990, coll. R. Hanley; NTM W4154, Buffalo Creek, 12°20.6'S 130°55.5'S, 4 November 1982, coll. R. Hanley.

Distribution. All Australian states and the Northern Territory.

Habitat. Shallow subtidal, associated with rocky reefs.

Remarks. This present material examined agrees well with the original description and material and represents the first record of the species from the Northern Territory.

Lanice sinata Hutchings and Glasby, 1990

Lanice sinata Hutchings and Glasby, 1990: 268-270, fig. 2a-h.

Material examined. Western Australia: AM W21847, Gantheaume Point, Broome, 17°58'S 122°14'E, LWM, in amongst algae, 1 July 1970, coll. E. Pope. Northern Territory: AM W21862, Lee Point, Darwin Harbour, 12°19'S 130°53'E, shallow, sandy substrate with *Caulerpa*, 19 July 1993, Jensen; NTM W4228, Ludmilla Creek, Darwin Harbour, 12°24.8'S 130°50.2'E, LWS, mudflat, 9 September 1986, coll. R. Hanley; AM W21846, Bangalow Hotel at Mandorah, Darwin Harbour, 12°27.3'S 130°46.0'E, intertidal, sandy substrate, 9 July 1993, coll. P Hutchings; AM W21866, Imalek Creek, Darwin Harbour 12°24'S 130°45'E, intertidal, crevice fauna, 7 July 1993, coll. P. Hutchings.

Distribution. Western Australia (Kimberley region), Northern Territory (Darwin Harbour).

Habitat. Intertidal sand flats.

Remarks. This species lives in a tube made of loosely cemented sand grains and shell fragments. A very characteristically shaped fan protrudes from the sand, with tube protruding 1-2 cm above the surface. This is the first record of the species from the Northern Territory.

Lanicides Hessle, 1917 emended

Lanicides Hessle, 1917: 165. - Hutchings and Glasby 1988: 20.

Type species. *Terebella (Phyzelia) bilobata* Grube, 1877, designated by Hessle, 1917.

Diagnosis. Branchiae, two or three pairs on segments 2,3 and 4; dichotomous branching. Lateral lobes present on segment 3, sometimes on peristomium. Notopodia from segment 4; notosetae smooth-tipped, some with serrated margins; neuropodia present from segment 5 (setiger 2), uncini initially long-shafted, becoming short-handled by mid thorax. Uncini initially arranged in single rows, on posterior thoracic segments arranged in double rows face to face; abdominal uncini arranged in single rows.

Remarks. The above generic diagnosis is that emended by Hutchings and Glasby (1988).

Lanicides attenuata Hutchings and Glasby, 1990

Lanicides attenuata Hutchings and Glasby, 1990: 270-272, fig. 3a-f.

Material examined. Western Australia: NTM W4875, caravan park, Roebuck Bay 17°58'S 122°14'E, LWS, 20 March 1987, coll. R. Hanley; NTM W4920, Ashmore Reef, 12°14'S 123°05'E, LWS, amongst coral agglomerate, 16 April 1987, coll. R. Hanley.

Habitat. Intertidal mud flats to shallow cryptic habitats in dead coral substrata.

Distribution. Western Australia (Dampier Archipelago; Broome), Ashmore Reef.

Remarks. The species was originally described from the Dampier Archipelago and these new records extend the distribution northwards.

Lanicides banatawa sp. nov.

Fig. 5A-H

Type material. HOLOTYPE - NTM W4233, Northern Territory, Weed Reef, Darwin Harbour, 12°30'S 129°48'E, 11 m, rocky reef, 8 June 1984, coll. R. Hanley. PARATYPES - NTM W9548, Flat Top Bank, 12°15'S 129°15'E, subtidal, sandy, 17 May 1992, coll. R. Hanley, complete but damaged and with regenerated posterior abdomen, 3 cm in length, 3 mm in width, with about 120 segments.

Description. *Holotype.* Alcohol preserved material pale cream with darker brown pigmentation encircling notopodial tori, dorsum more darkly pigmented. Complete, 2.5 cm in length, 3 mm in width with about 180 segments.

Tentacular membrane short, compact, with convoluted upper lip, glandular and pigmented on dorsal surface. Peristomium with numerous small eye spots. Numerous grooved buccal tentacles.

Three pairs of unequal sized branchiae on segments 2, 3 and 4, each branchia consisting of thick main long stalk, with numerous very short dichotomous branches. All branchiae aligned with notopodia, first pair largest and third pair smallest (Fig. 5A).

Notopodia beginning on segment 4, continuing for 17 segments. First one or two pairs of notopodia smaller than subsequent ones, progressively increasing in size, elongate, rectangular, posteriorly. Notosetae consisting of two tiers; long and medium in length, both broad-bladed with vertical striations, wide wings and narrow-pointed tips (Fig. 5C).

Neuropodia beginning on segment 5 (setiger 2), continuing to pygidium, tori increasing in length and becoming glandular to end of thorax. Notopodia and neuropodia arranged on same tori which form slightly raised structures. Abdominal uncinial tori decreasing in length posteriorly, forming slightly erect rectangular pinnules with rounded margins, posteriorly poorly developed. Uncini initially arranged in single rows, double rows from setiger 7 and again in single rows on abdominal segments. Thoracic uncini avicular, uncinigerous segment 1 with uncini with short, well developed shaft (Fig. 5D), easily broken, dental formula MF:3-4:2-3:∞, some variation within a row, uncinigerous segment 3 still with shaft but less developed and with similar dental formula to uncinigerous segment 1 (Fig. 5E). By uncinigerous segment 14, shaft completely absent (Fig. 5F) with dental formula MF:2-3:2-3. Abdominal uncini smaller than thoracic, with strongly crested head, often irregular accessory teeth, but approximate dental formula MF:2-3:5:6-10 (Fig. 5G,H).

Ventral surface with glandular, vertically pleated, discrete ventral pads (Fig. 5B) present to about setiger 14, then glandular area forming mid-glandular stripe. Dorsum rugose.

Lateral lobes present on peristomium and segment 3. Peristomial lateral lobe ventro-laterally displaced, rectangular in shape with glandular thickened bases with anterior margins thinner and convoluted, connected across ventral surface by narrow 'U' shaped fold. Segment 3 with triangular lateral lobes with ventral extension connecting across ventral surface, very glandular with thinner margins, apex of triangular portion deflected slightly dorsally (Fig. 5B).

Specimen with no coelomic gametes and no nephridial papillae visible.

Distribution. Northern Territory (Darwin Harbour; Flat Top Bank).

Habitat. Shallow subtidal on rocky reef habitat, in seagrasses and in sandy substrata.

Etymology. The specific name is the word for an ear used by the Larrakia people of the Darwin Harbour area (the type locality for the species), in reference to the lateral extension of the lateral lobe on segment 3.

Remarks. Hutchings (1993) provided a key to the Australian species of *Lanicides,* which now number six with this new species. Hutchings and Glasby (1988) emended the generic diagnosis and recorded the genus from Australia for the first time. They also indicated that many previously described species within the genus were poorly described, in terms of the description of shape and position of the lateral lobes,

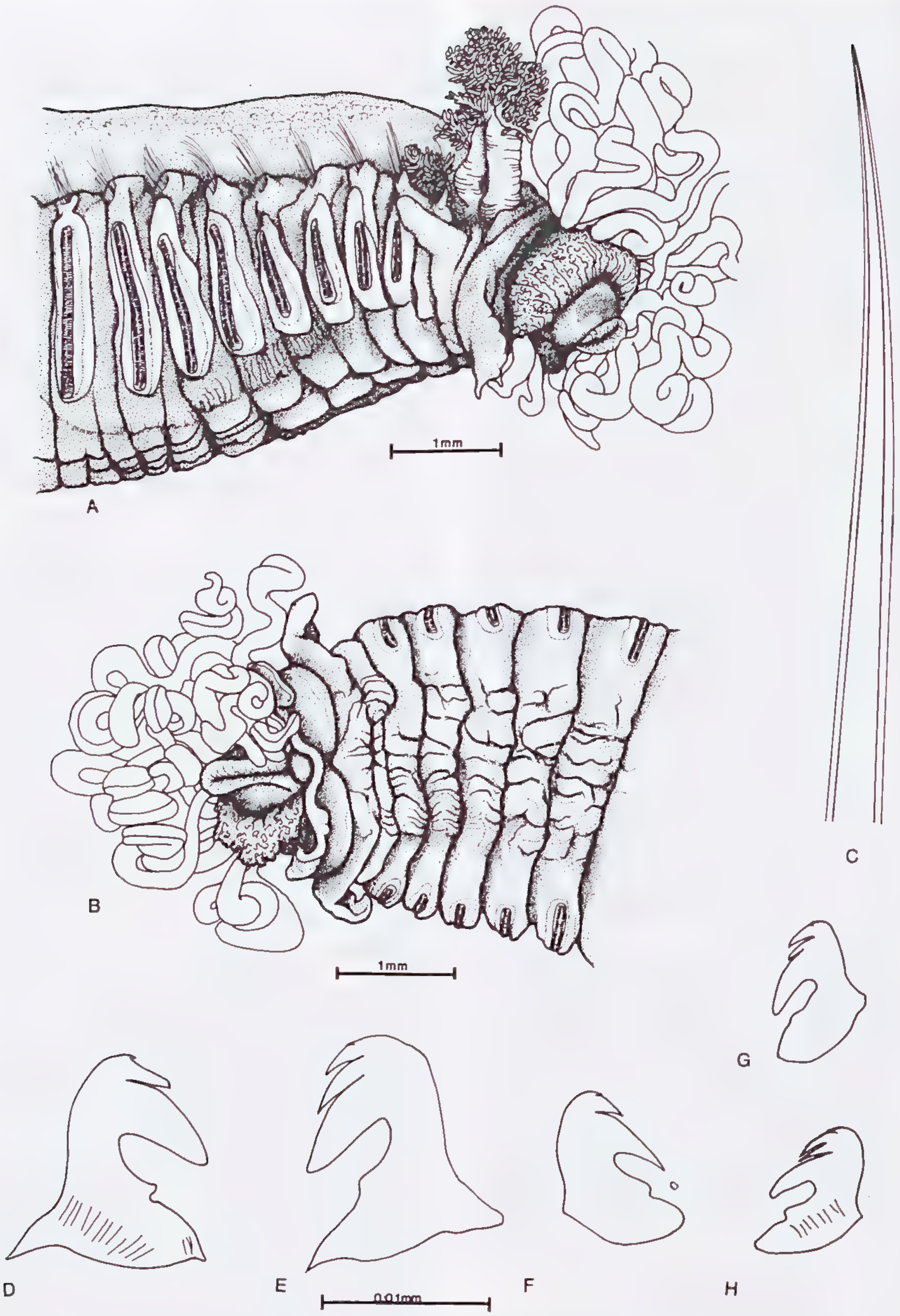

Fig. 5. *Lanicides banatawa* sp. nov. Holotype, NTM W4233: **A,** lateral view of prostomium and anterior segments; **B,** ventral view of anterior segments; **C,** thoracic notoseta from setiger 7, vertical striations not shown; **D,** lateral view of thoracic uncinus from setiger 1; **E,** lateral view of thoracic uncinus from setiger 3; **F,** lateral view of thoracic uncinus from setiger 15; **G, H,** lateral views of uncini from abdominal segment 10.

and may not in fact belong in the genus. However, any revision of the genus *Lanicides* must also consider other related genera with long-handled anterior uncini. *Lanicides banatawa* sp. nov. can be distinguished from other Australian species with three pairs of branchiae (*L. attenuata* Hutchings and Glasby, 1990, *L. tribranchiata* Hutchings and Glasby, 1988) by the shape of the peristomial lateral lobes and the lateral lobes on segment 3. In addition, the anterior uncini of *L. tribranchiata* are heavily chitinised and have a thicker shaft in comparison to *L. banatawa* sp. nov., which has poorly chitinised and not strongly elongated shafts. In this character only the new species resembles *L. attenuata*.

Lanicides fascia Hutchings and Glasby, 1988

Lanicides fascia Hutchings and Glasby, 1988: 21-22, fig. 7d-f.

Material examined. None.

Distribution. Western Australia (including Broome), and all other states except Northern Territory.

Habitat. Intertidal to shallow subtidal areas with hard substrata where the tube can be attached.

Remarks. Currently the species is not known from the Northern Territory, but it seems likely that the species should occur there as it is known from tropical areas such as Broome.

Lanicides tribranchiata Hutchings and Glasby, 1988

Lanicides tribranchiata Hutchings and Glasby, 1988: 22-24, figs. 8e-i, 9d-f; - 1990: 271.

Material examined. Northern Australia: AM W21869, Lee Point, Darwin Harbour, 12°20'S 130°53.8'E, 3-4 m, amongst coral rubble, 10 July 1993, coll. P. Hutchings.

Distribution. Northern Territory (Darwin Harbour), Western Australia (off Dongara), Bass Strait, Victoria, New South Wales.

Habitat. Coral rubble in shallow tropical waters and in temperate regions tubes found attached to solid substrata.

Remarks. This represents the first record of the species from the Northern Territory and a substantial range extension. Previously the most northern record was off Dongara on the Western Australian coast.

Lanicola Hartmann-Schröder, 1986

Lanicola Hartmann-Schröder, 1986: 58; - 1987: 58. - Hutchings and Glasby 1988: 24.

Type species. *Lanicola lobata* Hartmann-Schröder, 1986, by original designation.

Diagnosis. Eye spots present. Branchiae, two pairs on segments 2 and 3, dichotomously branched. Thorax with 17 pairs of notopodia from segment 4; notosetae smooth-tipped, narrow-winged capillaries. Neuropodia from segment 5 (setiger 2); uncini initially arranged in single rows, in double rows face to face in posterior thorax, again arranged in single rows on abdominal tori.

Lanicola lobata Hartmann-Schröder, 1986

Lanicola lobata Hartmann-Schröder, 1986: 56; - 1987: 58. - Hutchings and Glasby 1988: 24-26; - 1990: 273-274.

Material examined. Western Australia: NTM W4359, Gantheaume Point, Broome, 17°58'S 122°14'E, LWS, rock slab in silt, 15 March 1987, coll. R. Hanley; AM W21848, Gan-theaume Point, Broome, 17°58'S 122°14'E, LWM, in rock crevices, 3 July 1970, coll. E. Pope. Northern Territory: AM W21852, Lee Point, Darwin Harbour, 12°20'S 130°53.8'E, 3 m, dead coral substrate, 11 July 1993, coll. P. Hutchings; NTM W16002, Drimmie Arm, 12°11'45"S 136°41'17"E, St. C5, 0.9 m, 12 July 1991, coll. R. Hanley *et al.*

Distribution. Western Australia (Dampier Archipelago; Kimberley region), Northern Territory (Darwin Harbour; Gove), Victoria, South Australia.

Habitat. Intertidal to shallow subtidal, in crevices.

Remarks. The material agrees well with the expanded descriptions given by Hutchings and Glasby (1988, 1990). The monotypic genus was previously known only from NW Western Australia, South Australia and Victoria, and this represents the first record from the Northern Territory.

Loimia Malmgren, 1866

Loimia Malmgren, 1866: 380. - Hessle 1917: 170. - Hutchings and Glasby 1988: 26.

Type species. *Terebella medusa* Savigny, 1818, by monotypy.

Diagnosis. Branchiae, three pairs, dichotomously branched on segments 2, 3 and 4. Lateral lobes present. Notopodia from segment 4, present on following 17 segments; notosetae smooth-tipped, narrow-winged capillaries. Neuropodia from segment 5 (setiger 2); uncini with teeth arranged in vertical series in adults, initially in single rows, then in double rows back to back from uncinigerous segment 7 and all following thoracic segments; abdominal uncini arranged in single rows throughout.

Remarks. Hutchings and Glasby (1988) emended the generic diagnosis, noting that the uncinial teeth are arranged in a vertical series only in adults, thus juvenile specimens of *Loimia* are indeterminable.

Loimia ingens (Grube, 1878)

Loimia ingens - Hutchings and Glasby 1988: 28-30, fig. 11a-l; - 1990: 275-276.

Material examined. None.

Distribution. Western Australia and Northern Territory (Darwin Harbour).

Remarks. Hutchings and Glasby (1988) discussed this species in detail and concluded that *L. ingens* is a species complex, and a full description is given in that paper. Material from Darwin Harbour was examined for the above revision, but no additional material was collected during this study. *Loimia ingens* is only known from Darwin Harbour in the Northern Territory, and the common species of *Loimia* occurring in the area appears to be *L. ochracea*, see below.

Distribution. Australia (widespread, north of 35°S).

Loimia ochracea (Grube, 1878)

Fig. 6A-G

Terebella (Loimia) ochracea Grube, 1878: 547-548.

Loimia ochracea - Hutchings and Glasby 1988: 30.

Material examined. (A selection). Western Australia: NTM W6766, Napier, Broome Bay, 14°02'S 126°36'E, 0.3 m, under rocks in mud, 14 August 1991, coll. R. Hanley; Coral Sea: NTM 7176] Chesterfield Reef, 19°14'S 158°30'E, 16-20 m, coral near sand cay, 25 July 1988, coll. R. Hanley. Northern Territory: NTM W3485, Dugong Channel, mouth of McArthur River, 15°49'S 136°40.5'E, LWS, 6 August 1985, coll. R. Hanley; NTM W3832, Cora Point, mouth of McArthur River, 15°49'S 136°40.5'E, LWS, 3 August 1985, coll. R. Hanley; NTM W6999, north-east end of Wigram Island, 11°44'S 136°40.5'E, 6 m, rocky reef with some corals, 12 November 1990, coll. R. Hanley; NTM W943, NW Vernon Island, 12°03'S 131°02'E, 20 m, reef slope, 28 September 1982, coll. R. Hanley; AM W21864, Bangalow, Mandorah, Darwin Harbour, 12°27.3'S 130°46'E, intertidal sand flat, 9 July 1993, coll. P. Hutchings; AM W21887, (figured specimen), Bangalow, Mandorah, Darwin Harbour, 12°27.3'S 130°46'E, intertidal sand flat, 9 July 1993, coll. P. Hutchings; NTM W6144, Fannie Bay, Darwin Harbour, 12°27'S 130°49'E, MLW, under stones, 10 November 1989, coll. R. Hanley; NTM W1456, mouth of Ludmilla Creek, Darwin Harbour, 12°24'S 130°50.2'E, intertidal under stones, 20 May 1983, coll. R. Hanley; NTM W4792, Shell Island, East Arm, Darwin Harbour, 12°29.8'S 130°53.2'E, LW, 18 March 1988, coll. A. Mussig; AM W21860, Shell Island, East Arm, Darwin Harbour, 12°29.8'S 130°53.2'E, 2-3 m, dead coral substrate, 11 July 1993, coll. P. Hutchings; AM W21867, East Point, Darwin Harbour, 12°24.6'S 130°39.95'E, 7-10 m, dead coral substrate, 17 July 1993, coll. P. Hutchings; NTM W16003, Melville Bay, Gove, 12°11'45"S 136°41'17"E, St. A35 Wa, 9.4 m, green grey mud with some shell fragments, 21 March 1992, coll. R. Hanley *et al*; NTM W16004, Melville Bay, Gove, 12°11'45"S 136°41'17"E, St. B5 Wa, 5.7 m, green grey mud with shell grit, 26 March 1992, coll. R. Hanley *et al*; NTM W1782, Annesley Point, 11°24'S 122°51'E, LWS, in mangroves at base of cliffs, 18 June 1984, coll. R. Hanley; Marchinbar Island, 11°15'S 136°38'E, 6-7 m, in front of cliff face, 14 January 1990, coll. R. Hanley; NTM W3272, East Bay, Port Essington, 11°16'S 132°09'E, LWS, shell bank with mud, 19 September 1985, coll. R. Hanley; NTM W3391, Wangewanja Cove, Port Essington, 11°16'S 132°09'E, MLW, mud, 13 September 1985, coll. R. Hanley; NTM W3471, west side Barrow Bay, Port Essington, 11°16'S 132°09'E, LWS, mud flat in front of mangroves, 18 September 1985, coll. R. Hanley.

Distribution. Western Australia (Mermaid Cove, Dampier Archipelago; Napier Broome Bay), Northern Territory (widespread).

Habitat. Intertidal to shallow subtidal often associated with muddy and sandy sediments.

Description. Description based upon AM W21887. Robust worm with anterior body slightly ventro-dorsally flattened. Tentacular membrane short, compact prostomium with numerous grooved buccal tentacles arising from

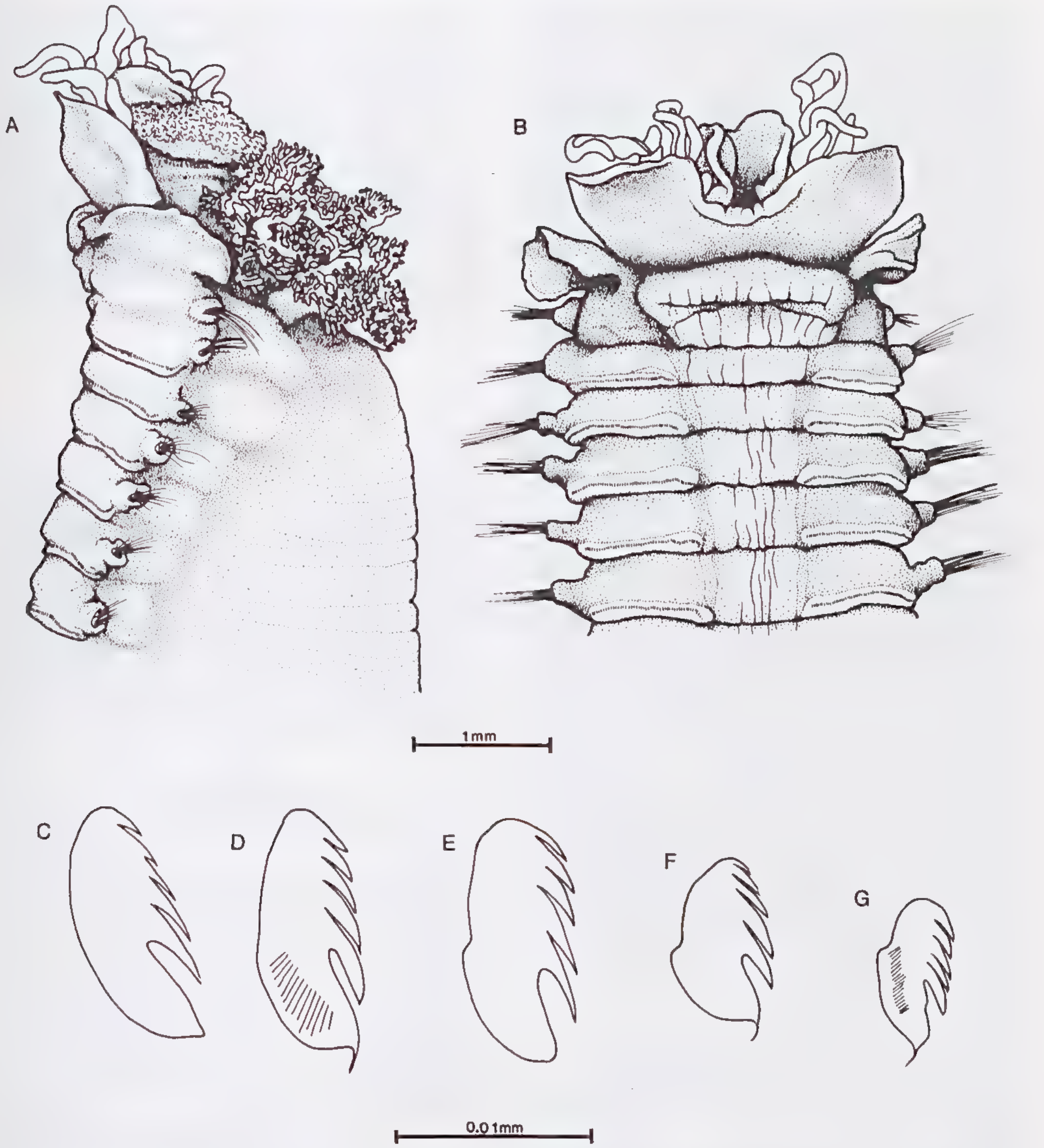

Fig. 6. *Loimia ochracea*. AM W21887: **A,** lateral view of prostomium and anterior segments; **B,** ventral view of anterior segments; **C, D, E,** lateral views of thoracic uncini from setiger 9; **F, G,** lateral views of uncini from abdominal segment 10.

thickened margins of prostomium. Few scattered lateral peristomial eye spots. Margin of peristomium expanded to form semi-circular lateral lobes which are connected mid-ventrally by 'U' shaped glandular connecting ridge, margins of peristomial lobes slightly convoluted. Lateral lobes absent on segment 2, present on segment 3 (Fig. 6A-B). Segment 3 with semi-circular lobes, glandular with fine, convoluted margins connected across ventral surface by connecting strip, margins of which extremely glandular and pleated (Fig. 6B).

Three pairs of branchiae on segments 2, 3 and 4, aligned longitudinally in line with notopodia, all branchiae similar in size, dichotomous branching with numerous short branches.

Notopodia from segment 4, continuing for 17 segments, podia elongate with numerous golden notosetae arranged in two tiers, setae broad-bladed with vertical striations, with narrow wings, smooth-tipped. Neuropodia from segment 5 (setiger 2) continuing to pygidium, uncini on long glandular tori, initially arranged in single rows, double rows from uncinigerous segment 7 for remaining thoracic segments, thereafter arranged in single rows. Posterior thoracic neuropodia elongate, almost meeting midventrally. Thoracic notopodia and neuropodia arranged on single glandular pad. Abdominal tori erect rectangular pinnules with slightly flared margins where uncini occur. Thoracic uncini with five teeth in vertical series (Fig. 6C-E), abdominal uncini similar in shape although smaller than thoracic ones (Fig. 6F-G).

Ventral pads discrete, forming distinctive 'U' shaped ventral structure, cream coloured pads, gradually tapering posteriorly, forming ventral glandular stripe by setiger 16. Ventral pads initially vertically pleated, posterior pads with transverse markings. Dorsum smooth, partially transparent revealing some internal structures.

Nephridial papillae not visible. Coelom filled with sperm morulae.

Remarks. Hutchings and Glasby (1988) redescribed the incomplete type of *L. ochracea* collected from Mermaid Cove in the Dampier Archipelago and at that time no other material was available. During the present study a large amount of material of this species from the Museum and Art Gallery of the Northern Territory, Darwin, became available for study. Therefore an expanded description of the species is given above. Additional figures are also provided to clearly document the distribution of the lateral lobes, etc, which are not well preserved in the type specimen and therefore were not figured by Hutchings and Glasby (1988).

Nicolea Malmgren, 1866

Nicolea - Hutchings and Glasby 1988: 35.

Type species. *Terebella zostericola* Ørsted, 1844, subsequent designation by Malmgren, 1866.

Diagnosis. Branchiae, two pairs, dichotomously branched. Lateral lobes absent. Notopodia from segment 4, 15-40 pairs; notosetae smooth-tipped capillaries. Neuropodia from segment 5 (setiger 2); uncini arranged in double rows on posterior thoracic segments.

Nicolea amnis
Hutchings and Murray, 1984

Nicolea amnis Hutchings and Murray, 1984: 98-100, fig. 29, 1-3. - Hutchings and Glasby 1988: 35-36; - 1990: 276.

Material examined. Northern Territory: AM W21856, Lee Point, Darwin Harbour, 12°20'S 130°53.8'E, intertidal, sandy beach with *Caulerpa*, 19 July 1993, coll. K. Jensen.

Distribution. Widespread within Australia.

Habitat. Amongst the green alga *Caulerpa*; 33 individuals were found within a single clump.

Remarks. This species appears to occur throughout Australian intertidal and shallow water areas. An additional specimen from Shark Bay (ex NTM W6458) was examined, and is mentioned here as the species was not previously known north of Cockburn Sound in Western Australia.

Phisidia Saint-Joseph, 1894

Phisidia Saint-Joseph, 1894: 167.

Type species. *Leaena oculata* Langerhans, 1880, by monotypy.

Diagnosis. Branchiae absent. Lateral lobes absent. Notopodia, 14 pairs, from segment 4; notosetae distally denticulate, two types present, shorter setae with coarser, pectinate appearance, longer setae fine and faintly denticulate. Neuropodia from segment 5 (setiger 2); uncini, arranged in double rows face to face on posterior thoracic segments.

Phisidia echuca
Hutchings and Glasby, 1988

Phisidia echuca Hutchings and Glasby, 1988: 36-38, fig. 14a-d; - 1990: 277.

Material examined. Northern Territory: NTM W6171, Ashmore Reef, 12°14'S 123°05'E, LWS, reef flat, 15 April 1987, coll. R. Hanley.

Distribution. Northern Territory (Ashmore Reef), Western Australia (Albany), South Australia, Victoria, New South Wales.

Habitat. Reef flat.

Remarks. The single specimen agrees well with the original description and material examined by Hutchings and Glasby (1988), except that well developed eye spots are present; however, this is not regarded as a critical specific characteristic. This is the first record of the genus and species in northern Australia.

Pista Malmgren, 1866, emended

Pista Malmgren, 1866: 382. - Hutchings and Glasby 1988: 38-39.

Type species. *Amphitrite cristata* O.F. Müller, 1776, by monotypy.

Diagnosis. Tentacular lobe with numerous buccal tentacles. Lateral lobes on segments 2-4 and sometimes on peristomium. Branchiae, one to three pairs on segments 2-4. Notopodia from segment 4, continuing for 17 segments; notosetae smooth-tipped, winged capillaries. Neuropodia beginning on segment 5 (setiger 2); uncini of anterior thoracic segments typically with posteriorly elongated bases (=long handled), following uncini lacking elongated bases. Uncini arranged in single rows initially, in double rows from uncinigerous segment 7 to end of thorax, abdominal uncini arranged in single rows.

Pista australis Hutchings and Glasby, 1988

Pista australis Hutchings and Glasby, 1988: 40-41, fig. 15a-f.

Material examined. Northern Territory: AM W21821, North Shell Island, Darwin Harbour, 12°29.8'S 130°53.2'E, 8 m, sponge and algal covered coral rubble, 16 July 1993, coll. P. Hutchings; AM W21824, Weed Reef, Darwin Harbour, 12°30'S 130°48'E, 5 m, dead coral rubble, 6 July 1993, coll. P. Hutchings.

Distribution. Northern Territory (Darwin Harbour, Gove), South Australia, Bass Strait, Victoria, New South Wales.

Habitat. Associated with dead coral substrata in the tropics and with seagrass beds in temperate regions.

Remarks. This is the first record of the species from northern Australia.

Pista curtiuncata Hartmann-Schröder, 1981

Pista curtiuncata Hartmann-Schröder, 1981: 58, figs 134-136; - 1985: 86; - Hutchings and Glasby 1988: 41- 42, fig. 16a; - 1990: 279-280.

Material examined. Western Australia: NTM W14024, Broome jetty, 17°59'S 122°15'E, 20 March 1987, coll. R. Hanley; Northern Territory: AM W21870, between North and South Shell Islands, Darwin Harbour, 12°29.8'S 130° 53.2'E, 3 m, dead coral rubble, 11 July 1993, coll. P. Hutchings; NTM W16005, Melville Bay, Gove, 12°19.5'S 130°53.5'E, St. D5, 12.9 m, 22 March 1992, coll. R. Hanley *et al.*

Distribution. Western Australia (North West), Northern Territory (Arafura Sea; Gove), Queensland (Townsville; Calliope River, Gladstone).

Habitat. In amongst coral rubble, no habitat details given for the material collected from Broome and Gove.

Remarks. The species has previously been recorded from northern Australia.

Pista gwoyarrma sp. nov.
Fig. 7A-F

Type material. HOLOTYPE - NTM W9551, Northern Territory, Frances Bay, Darwin Harbour, 12°28'33"S 130°49'17"E, 25 m, 17 July 1993, coll. NTM staff. PARATYPE - NTM W9552, Northern Territory, Frances Bay, Darwin Harbour, 12°28'33"S 130°49'17"E, 25 m, 17 July 1993, coll. NTM staff, complete, 8 mm in length, 1.5 mm in width, with about 57 segments.

Description. *Holotype.* Alcohol preserved body colourless, posteriorly incomplete. 10 mm in length and 2.5 mm in width for 40 setigers.

Tentacular membrane short and compact with few remaining grooved buccal tentacles. Peristomial eye spots absent. Peristomium present as simple ring not expanded to form lateral lobe. Two pairs of tufted plume-shaped branchiae on segments 2 and 3, first pair much larger than ssecond pair. Branchiae with branches arranged in series of discrete horizontal tiers.

Lateral lobes present on segments 2, 3 and 4; segment 2 with rectangular lobe slightly displaced laterally and continuing across ventral surface as rectangular shaped structure. Segment 3 with small semi-circular lobe, less developed towards ventral surface, connected midventrally by narrow glandular strip. Segment 4 with small, poorly developed, semi-circular lobe, displaced slightly dorsally to those on segment 3, continuing across venter as narrow connecting strip, forming almost anterior extension of segmental margin (Fig. 7A-B).

Notopodia beginning on segment 4 and continuing for 17 segments, anterior notopodia smaller than posterior notopodia, tori short rectangular with golden setae. Notosetae arranged in two tiers, long and medium in length, both types long-bladed, with blade expanded with narrow wings just behind apex, tips narrow and non-striated (Fig. 7C).

Neuropodia from segment 5 (setiger 2) and occurring on all subsequent segments. Thoracic neuropodia elongate, abdominal ones short and slightly erect, with slightly inflated tips. Uncini initially arranged in single rows, in double rows from uncinigerous segment 7, and all subsequent thoracic segments, again arranged in single rows on abdominal segments. Uncini of first

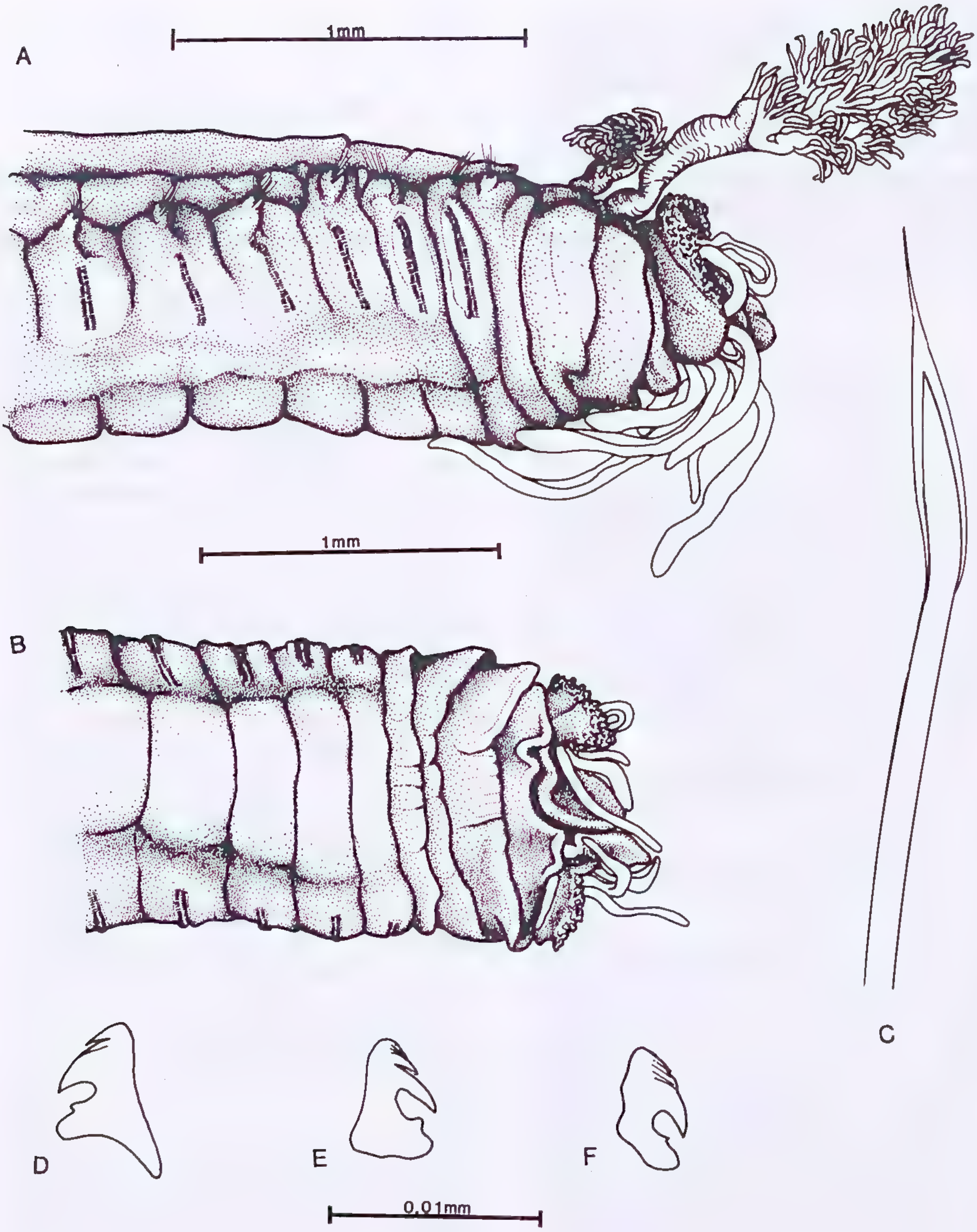

Fig. 7. *Pista gwoyarrma* sp. nov. Holotype NTM W9551: **A,** lateral view of prostomium and anterior segments; **B,** ventral view of anterior segments; **C,** thoracic notoseta from setiger 12; **D,** lateral view of thoracic uncinus from setiger 1; **E,** lateral view of thoracic uncinus from setiger 3; **F,** lateral view of uncinus from anterior abdominal segment.

uncinigerous segment avicular with strongly crested head and short thick shaft, dental formula MF:5-6:5-6:∞ (Fig. 7D), by third uncinigerous segment shaft absent (Fig. 7E). Abdominal uncini slightly smaller than thoracic uncini with strongly crested head, MF:6-8:6-8:∞, about 10-12 uncini within a torus (Fig. 7F).

Ventral pads well developed and segmentally demarcated to end of thorax, then continuing into mid-ventral glandular stripe. Ventral pads smooth, well demarcated laterally from neuropodial tori. Dorsum smooth but longitudinal muscles visible through body wall. White glandular tissue present around bases of notopodia, thoracic neuropodial tori not markedly glandular and flat.

Nephridial papillae present on setigers 3 and 4 (segments 6 and 7), dorso-laterally to notopodia.

Distribution. Northern Territory (Darwin Harbour).

Habitat. Subtidal in muddy sediments.

Etymology. The specific name is the word for a feather used by the Larrakia people of Darwin Harbour, the type locality of this species, in reference to the structure of the plume-shaped branchiae.

Remarks. Hutchings and Glasby (1990) provided a key to the species of *Pista* recorded from Western Australia which included all of the species of *Pista* recorded from the Northern Territory in this study. Only four other species of Australian species of *Pista* have two pairs of plume-shaped branchiae, *P. australis* Hutchings and Glasby, 1988, *P. curtiuncata* Hartmann-Schröder, 1981, *P. typha* Grube, 1878, and *P. anthela* Hutchings and Glasby, 1990. *Pista gwoyarrma* sp. nov. can be distinguished from *P. anthela*, *P. curtiuncata* and *P. typha* by the lack of peristomial lobes which are well developed on all these species. *Pista australis* can be distinguished from *P. gwoyarrma* sp. nov. by the shape and arrangement of lateral lobes on segments 2-4.

Pista kimberliensis Hutchings and Glasby, 1990

Pista kimberliensis Hutchings and Glasby, 1990: 280-282, fig. 5a-f.

Material examined. Northern Territory: NTM W4556, Ashmore Reef, 12°14'S 123°05'E, MLW, sandy reef flat, 20 April 1987, coll. R. Hanley; AM W21829, Channel Island, Darwin Harbour, 12°32.85'S 130°51.8'E, LWS, in amongst *Caulerpa*, 20 July 1993, coll. P. Hutchings; AM W21828, Mandorah, Darwin Harbour, 12°27.3'S 130°46.0'E, LWS, muddy sandy substrate, 9 July 1993, coll. P. Hutchings; NTM W16006 Melville Bay, Gove, 12°11'45"S 136°41'17"E, St. D7 Wa, 7.2 m, sand, 25 July 1991, coll. R. Hanley *et al.*

Distribution. Northern Territory (Darwin Harbour), Western Australia (Kimberley region).

Habitat. Intertidal mud and sand flats, often with associated mangroves and shallow subtidal areas.

Remarks. This is the first record of the species from Northern Territory, it was previously only known from the Kimberley region.

Pista violacea Hartmann-Schröder, 1984

Pista violacea Hartmann-Schröder, 1984: 45, figs 54-60. - Hutchings and Glasby 1988: 47-49, fig. 18a-b; - 1990: 282-283.

Material examined. Northern Territory: NTM W4847, East Arm boat ramp, Darwin Harbour, 12°27'S 130°51.08'E, LW, mud flats in front of mangroves, 1 June 1987, coll. R. Hanley; AM W21854, West Point, Darwin Harbour, 12°26.24'S 130°46'E, dead coral rubble, 6-8 m, 17 July 1993, coll. P. Hutchings; NTM W3200, Mangrove Point, Port Essington, 11°16'S 132°09'E, LWS, rocky reef, 15 September 1985, coll. R. Hanley; NTM W16007, Melville Bay, Gove, 12°11'45"S 136°41'17"E, St. D5 Wa, 12.9 m, 22 March 1992, coll. R. Hanley *et al.*; NTM W16008, Melville Bay, Gove, 12°11'45"S 136°41'17"E, St. A16, 2.7 m, coarse sand, 7 July 1991, coll. R. Hanley *et al.*

Distribution. All Australian states except Queensland.

Habitat. Intertidal to shallow subtidal areas, with sand and muddy substrata.

Remarks. The material examined agrees well with the previous descriptions although the intensity of pigmentation varies between individuals.

Pseudoproclea Hutchings and Glasby, 1990

Pseudoproclea Hutchings and Glasby, 1990: 283.

Type species. *Pseudoproclea australis* Hutchings and Glasby, 1990, by original designation.

Diagnosis. Peristomial eye spots present or absent. Branchiae absent. Lateral lobes absent. Notopodia beginning on segment 4 and continuing for 16 segments. Notosetae mixture of smooth-tipped, broad-bladed capillaries and capillaries with finely denticulated margins. Neuropodia from segment 5, (setiger 2); uncini arranged in double rows on posterior thorax and part of abdomen.

Pseudoproclea australis Hutchings and Glasby, 1990

Pseudoproclea australis Hutchings and Glasby, 1990: 283-285, fig. 6a-h.

Material examined. None.

Distribution. Western Australia (Dampier Archipelago; Kimberley region).

Habitat. Intertidal to shallow subtidal communities, associated with crevice fauna, or under boulders.

Remarks. *Pseudoproclea australis* has been described from the Dampier Archipelago and the Kimberley region in Western Australia, and although no material was collected during this study, it seems likely that the species occurs in the Northern Territory.

Terebella Linnaeus, 1767

Terebella - Hessle 1917: 187; - Hutchings and Glasby 1988: 51-53.

Type species. *Terebella lapidaria* Linnaeus, 1767, by monotypy.

Diagnosis. Three pairs of dichotomously branched branchiae from segment 2. Lateral lobes absent. Notopodia from segment 4, continuing for variable number of segments; notosetae distally serrated. Neuropodia from segment 5 (setiger 2); uncini initially arranged in single rows, from uncinigerous segment 7 to end of thorax, arranged in double rows face to face or alternately; abdominal uncini arranged in single rows. Nephridial papillae from segment 3.

Remarks. Hutchings and Glasby (1988), emended the generic diagnosis, in order to include several species of Australian *Terebella*.

Terebella maculata Hutchings and Glasby, 1988

Terebella maculata Hutchings and Glasby, 1988: 53, fig. 21a-h; - 1990: 285.

Material examined. Northern Territory: NTM W14019, Port Essington, 11°16'S 132°09'E, 11 September 1985, coll. R. Hanley; NTM W3879, Port Essington, 11°16'S 132°09'E, 11 September 1985, coll. R. Hanley.

Distribution. Western Australia (Dampier Archipelago; Lacepede Group; Kimberley region), Northern Territory (Essington).

Habitat. No habitat information available for Northern Territory material but elsewhere the species occurs intertidally as crevice fauna.

Remarks. The material examined agrees well with the original description. This represents the first record from the Northern Territory.

Terebella pappus Hutchings and Murray, 1984

Terebella pappus Hutchings and Murray, 1984: 100-101, fig. 30: 1-2 - Hutchings and Glasby, 1988: 53-54, fig. 22a-d; - 1990: 286.

Material examined. None.

Distribution. Western Australia (entire coast) and southern Australian waters.

Habitat. Intertidal as crevice fauna.

Remarks. The species was originally thought to be a southern species, but its occurrence all along the coast of Western Australia indicates that it is more widespread (Hutchings and Glasby 1990). As the species occurs in the Kimberley region, it may also occur in the Northern Territory although no material was found during this study. It co-occurs with *T. tantabiddycreekensis* Hartmann-Schröder, in some Western Australia localities.

Terebella tantabiddycreekensis Hartmann-Schröder, 1980

Terebella tantabiddycreekensis Hartmann-Schröder, 1980: 77-78, figs 122-123. - Hutchings and Glasby 1988: 55-56; - 1990: 286.

Material examined. (A selection). Northern Territory: AM W21839, Sadgrove Creek, Darwin Harbour, 12°27'S 130°51.25'E, intertidal, found in dead wood lying on mangrove floor, 10 July 1993, coll. P. Hutchings; AM W21858, Mandorah, Darwin Harbour, 12°27.3'S 130°46'E, intertidal, crevice fauna, 8 July 1993, coll. P. Hutchings; NTM W4744, Creek H, East Arm, Darwin Harbour, 12°34.2'S 130°56.3'E, LWM, inside rotting timber, 11 February 1987, coll. R. Hanley; NTM W3604, West Bay, Port Essington, 11°16'S 132°09'E, MLW, inside rotting wood on mangrove floor, 13 September 1985, coll. R. Hanley; NTM W3354, Wangewanja Cove, Port Essington, 11°16'S 132°09'E, MLW, inside rotting wood amongst *Rhizophora*, 13 September 1985, coll. R. Hanley.

Distribution. Western Australia (widespread), Northern Territory (Darwin Harbour; Port Essington) and Queensland (north of 35°S).

Habitat. All the specimens examined were found in heavily bored and rotten wood lying on the floor of mangrove forests.

Remarks. The material examined agrees well with the original description and material, together with the additional comments by Hutchings and Glasby (1988).

DISCUSSION

This study of terebellids collected during the Workshop and supplemented by the collections of the Museum and Art Gallery of the Northern Territory has revealed the presence of at least six new species. An additional undescribed species of *Polycirrus* will be described in a forthcoming revision of the genus by Hutchings and Glasby (in manuscript). Of the 34 species recorded from northern Australia in this paper, five represent new generic records and 14 are new species records for the Northern Territory. This highlights our limited knowledge of the Australian polychaete fauna, especially in tropical areas. Because the polychaete fauna of South East Asia is also poorly known it is difficult to compare the polychaete fauna of northern Australia to it. It should also be stressed that the collections available for study were limited in the range of locations. Most were intertidal and shallow subtidal, with the eastern areas of northern Australia poorly represented. Therefore it seems highly likely that additional new species and new records will be found in the area with further collecting. Therefore users of the key should be aware that other species which are not included in the key may occur in the area and all species should be carefully checked against the original descriptions.

This paper represents one of a series describing the terebellid fauna of Australia (Hutchings and Glasby 1986a, 1987, 1988, 1990; Hutchings 1993). Some generalisations on the distribution of one of the larger polychaete families can now be made. It appears that distribution patterns vary even within a genus. For example, *Terebella pappus* and *T. tantabiddycreekensis* have wide geographical distributions whereas *T. maculata* has a far more restricted distributional pattern. The same appears to occur in the genus *Loimia*. There also appear to be species that occur almost throughout Australia such as *Nicolea amnis* and *Eupolymnia koorangia* and others that have a northern or southern distribution, *Polycirrus broomensis* and *Hadrachaete aspeta* Hutchings, 1977, respectively. This may be a reflection of breeding strategies or habitat requirements, although at this stage any suggestion of the factors responsible for the distributional patterns is purely speculative.

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SACOGLOSSA (MOLLUSCA, OPISTHOBRANCHIA) FROM THE DARWIN HARBOUR AREA, NORTHERN TERRITORY, AUSTRALIA.

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ABSTRACT

Eight species of Sacoglossa (Mollusca, Opisthobranchia) were collected during the Sixth International Marine Biological Workshop held in Darwin, Northern Territory, Australia, 5-23 July 1993. Four of these are new to science: *Volvatella australis* n. sp., *Berthelinia darwini* n. sp., *Costasiella mandorahae* n. sp., and *Elysiella stylifera* n. sp. The other four species, *Elysia australis* (Quoy and Gaimard, 1832), *Elysiella pusilla* Bergh, 1872, *"Stiliger" smaragdinus* Baba, 1949, and *Ercolania translucens* Jensen, 1993, are recorded from the Northern Territory for the first time. Observations on feeding and reproductive biology have been included in the descriptions where possible.

KEYWORDS: Mollusca, Opisthobranchia, Sacoglossa, taxonomy, morphology, systematics, Australia.

INTRODUCTION

The present paper is a continuation of the description of Australian Sacoglossa begun at the Third International Marine Biological Workshop, held in Albany, Western Australia, in January 1988 (Jensen and Wells 1990), and continued at the Fifth International Marine Biological Workshop, held at Rottnest Island, Western Australia in January 1991 (Jensen 1993a). Prior to these works, about 25 species of Sacoglossa had been recorded from Australia, mainly through the efforts of Mr. R. Burn, Geelong, Victoria (e.g. Burn 1960, 1965, 1972, 1989). Most earlier descriptions have been very brief, barely adequate for reidentifying the species. As anatomical characters are necessary for comparing species from different parts of the world, and also for identifying phylogenetic relationships, it is important to have detailed anatomical descriptions, as well as observations on behaviour of these animals. The present paper presents descriptions of sacoglossans collected at the Sixth International Marine Biological Workshop held in Darwin in July 1993. A total of eight species of Sacoglossa were collected. These are all "new records" for the Northern Territory. Four of these, *Elysia australis* (Quoy and Gaimard, 1832), *Elysiella pusilla* Bergh, 1872, *'Stiliger' smaragdinus* Baba, 1949 and *Ercolania translucens* Jensen, 1993, have previously been described anatomically (Jensen and Wells 1990; Jensen 1993a).

Materials and methods. Collection data are listed below for each species. Specimens were relaxed in 8% $MgCl_2$ mixed with seawater (1:1) and fixed in 4% neutral formaldehyde. Specimens were then transferred to 70% ethanol. Fine dissection and preparation of radular teeth and penial armature for SEM was done as described previously (Jensen 1993a).

Institutional abbreviations: NTM, Museum and Art Gallery of the Northern Territory, Darwin, Australia; ZMH, Finnish Museum of Natu-

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In: Hanley, J.R., Caswell, G., Megirian, D. and Larson, H.K. (eds) *Proceedings of the Six International Marine Biological Workshop. The marine flora and fauna of Darwin Harbour, Northern Territory, Australia.* Museums and Art Galleries of the Northern Territory and the Australian Marine Sciences Association: Darwin, Australia, 1997: 163–186.

ral History, Zoological Museum, Helsinki; ZMUC, Zoological Museum, University of Copenhagen, Denmark. Material for which no institutional repository is indicated is presently held by the author.

SYSTEMATICS

Family Volvatellidae Pilsbry, 1895

This family contains the genera *Ascobulla* and *Volvatella*. However, no "good" familial synapomorphies have been described, so that it may be paraphyletic. The genera included are the most primitive sacoglossans, and they are characterized mostly by plesiomorphic characters, e.g. the large shell, non-pigmented body, short foot, narrow neck, and by generic autapomorphies.

Genus *Volvatella* Pease, 1860

Volvatella Pease, 1860.
Arthessa Evans, 1950.

Volvatella has a thin, flexible, bulloid shell with a posterior spout. The animal can be completely retracted into the shell. The head-foot is usually unpigmented; the mantle fold may be orange or green. There is no cephalic shield, but a pair of grooved anterior tentacles and a pair of dorsal, triangular tentacles. The radular teeth are triangular with lateral denticles and often a hooked tip of cusp. There is a large, round pharyngeal pouch. The penis may be armed with a short cuticular stylet.

Volvatella australis n. sp.

Type material. HOLOTYPE - NTM P6968, shell length 4.5 mm, Lee Point, on *Caulerpa* spp., 20 July 1993, coll. K.R. Jensen. PARATYPES - 1 specimen (ZMUC), shell length 4 mm, Lee Point, 20 July 1993; 1 specimen (ZMH), shell length 3.5 mm, Lee Point, 20 July 1993, coll. K.R. Jensen.

Other material. 3 specimens, K.R. Jensen, Lee Point, 6 July, 1993; many specimens (8 dissected), K.R. Jensen, Lee Point, 20 July, 1993.

Description. *Shell.* The shell of the largest specimen was about 13 mm long; the smallest was less than 1 mm, and still had the protoconch visibly protruding posteriorly. The shell is completely transparent, very thin and fragile; several specimens had fracture-lines in the shell. The shell is almost cylindrical, in living specimens somewhat contracted anteriorly (Fig. 1). The spout is short and pointing directly

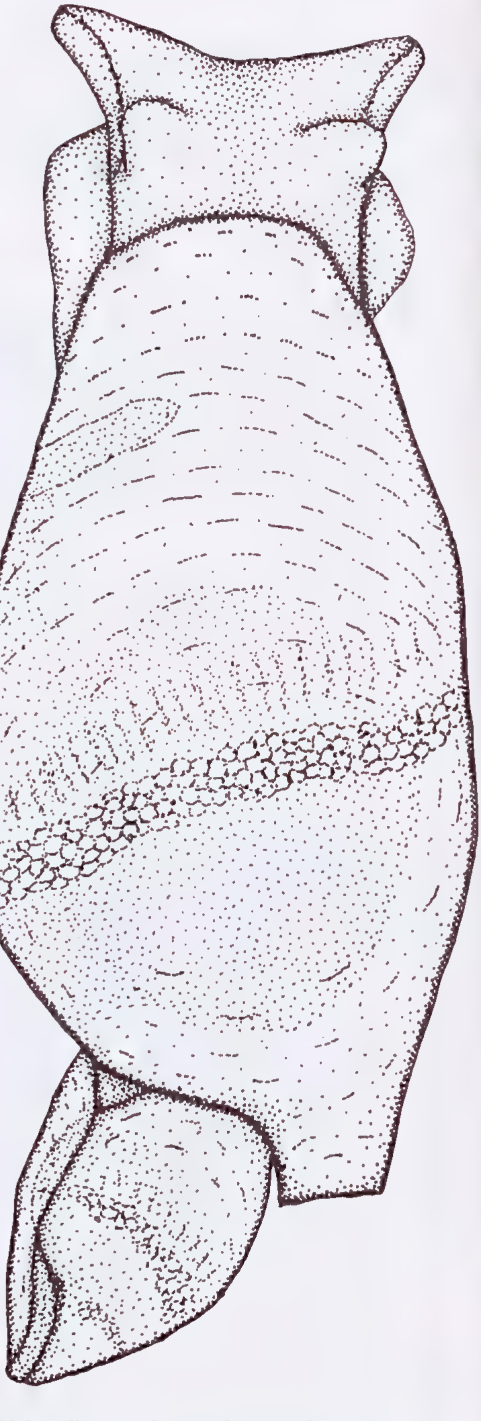

Fig. 1. *Volvatella australis* n. sp. Live specimens drawn from colour slide by K.R. Jensen. The shell of the large specimen was about 12 mm. The figure shows the typical position of a small specimen "riding" on a larger specimen, waiting for an opportunity to copulate.

posteriorly; it is located to the right of the midline. The outer lip overlaps the reflected inner lip for about half the shell length (Fig. 2). There is a narrow umbilicus. The protoconch in specimens bigger than 2 mm is completely hidden by the reflected inner lip of the following whorls. After removal of the body whorl it can be seen through the transparent "columella" (Figs 3C, 5A).

Colour alive. The body is white, but the pale green digestive gland may be visible through the epidermis of the visceral mass, and sometimes even through the mantle and shell. There may also be some digestive gland tubules in the mantle fold; some specimens have pale green mantles anterior and to the left of the pericardium. White dots were especially dense along the mantle edge, forming white bands anteriorly and along the posterior spout.

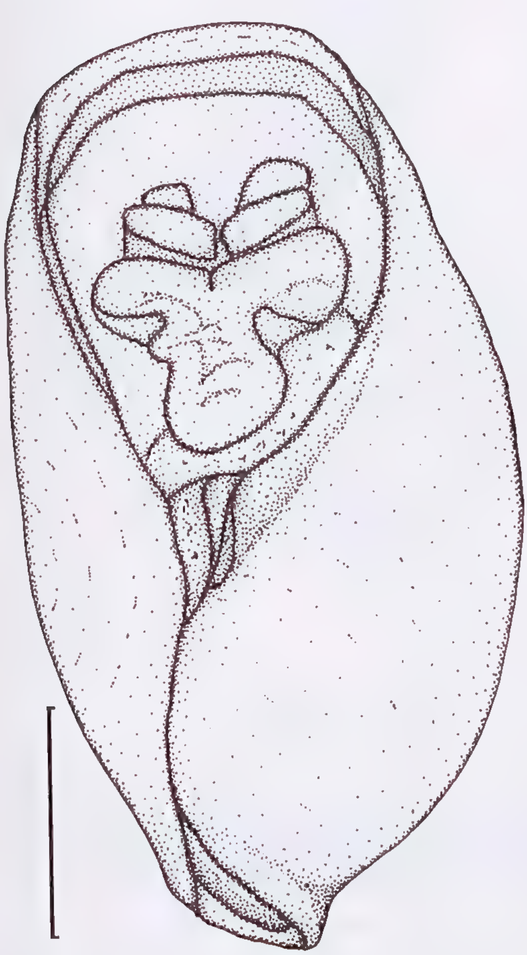

Fig. 2. *Volvatella australis* n. sp. Ventral view of preserved specimen. Scale bar = 1 mm.

External features. The head is deeply notched mid-anteriorly (Figs 1, 2, 3A). The anterior cephalic tentacles are triangular with a lateral groove; the eyes are visible above this groove. The ventral lobes of the anterior tentacles continue as oral lobes surrounding the mouth (Fig. 3A). The dorsal tentacles are short and triangular. The foot is short and rounded anteriorly as well as posteriorly; the posterior end is slightly narrower than the anterior end. There is a distinct spawn groove on the right side, extending from the female genital papilla to the mouth area (Fig. 3A). The penial aperture is located at the posterior end of the groove in the right anterior tentacle, i.e. above the spawn groove.

Pallial organs. The mantle fold is continuous around the body; where the inner lip of the shell reflects, the mantle edge continues around the thick infrapallial lobe (Figs 2, 3B). Here the mantle as well as the infrapallial lobe are firmly attached to the visceral mass, and it is through this connection that branches of the digestive gland penetrate. Posteriorly the mantle edge and the infrapallial lobe bear a series of small, ciliated, glandular bosses, which secrete a milky-white secretion if the animal is disturbed. The mantle fold is attached to the neck of the animal by a narrow, but strong, adhesive ridge all the way across the head. From the adhesive ridge to the extremely narrow connection to the visceral mass, the cephalic organs are covered by a thin but strong diaphragm. The gill extends all the way around the body whorl, but not into the pallial caecum. It consists of numerous, low, ciliated lamellae attached to the surface of the kidney. The heart is almost transverse in front of the gill (Fig. 4A). The shell adductor muscle attaches just in front of the anterior right corner of the gill, and a small, oval osphradium is located at the base of the adductor muscle. The other attachment of the diagonal adductor muscle is on the left ventral side, where the inner lip begins to reflect. Behind the gill is a narrow band of white glands, which are visible through the shell. Behind this is the inconspicuous dorsal raphe followed by another band of opaque, whitish glands. The glandular bands accompany the ciliated raphe into the pallial caecum, which is "attached" all the way, i.e. it is a continuation of the mantle cavity into the upper whorls of the shell. In the mantle floor are two conspicuous humps; one, on the left anterior side, is the mucus gland of the female reproductive system, and the other, more posterior one,

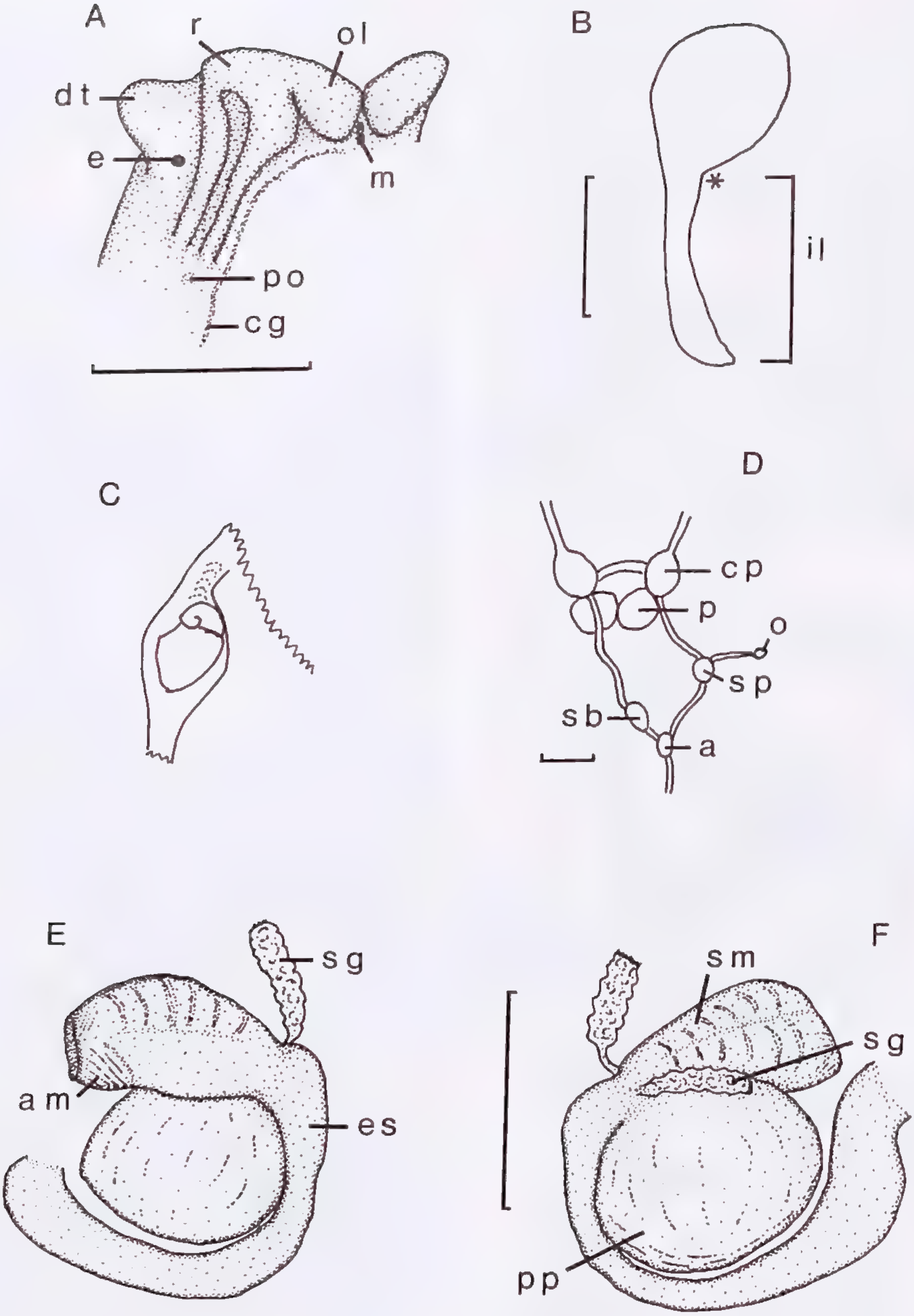

Fig. 3. Anatomy of *Volvatella australis* n. sp. **A**, lateral view of anterior region, showing grooved anterior tentacles, eye, penial opening and spawn groove. **B**, outline of mantle edge showing the connection of the mantle lobe to the infrapallial lobe and the visceral mass (asterisk). **C**, "columella" after removal of body whorl, showing protoconch and first whorl covered by transparent callus (reflected inner lip). **D**, central nervous system. **E**, pharynx, latero-ventral view of left side. **F**, pharynx, latero-dorsal view of right side. Scale bars: **A, E, F** = 0.5 mm; **B** = 1 mm; **D** = 0.1 mm. Abbreviations: **a**, abdominal ganglion; **am**, ascus-muscle; **cg**, ciliated spawn groove; **cp**, cerebro-pleural ganglion; **dt**, dorsal (posterior) cephalic tentacle; **e**, eye; **es**, oesophagus; **il**, infrapallial lobe; **m**, mouth; **o**, osphradial ganglion; **ol**, oral lobe; **p**, pedal ganglion; **po**, penial opening; **pp**, pharyngeal pouch; **r**, rhinophore (= anterior cephalic tentacle); **sb**, subintestinal ganglion; **sg**, salivary gland (cut); **sm**, dorsal septate muscle; **sp**, supraintestinal ganglion.

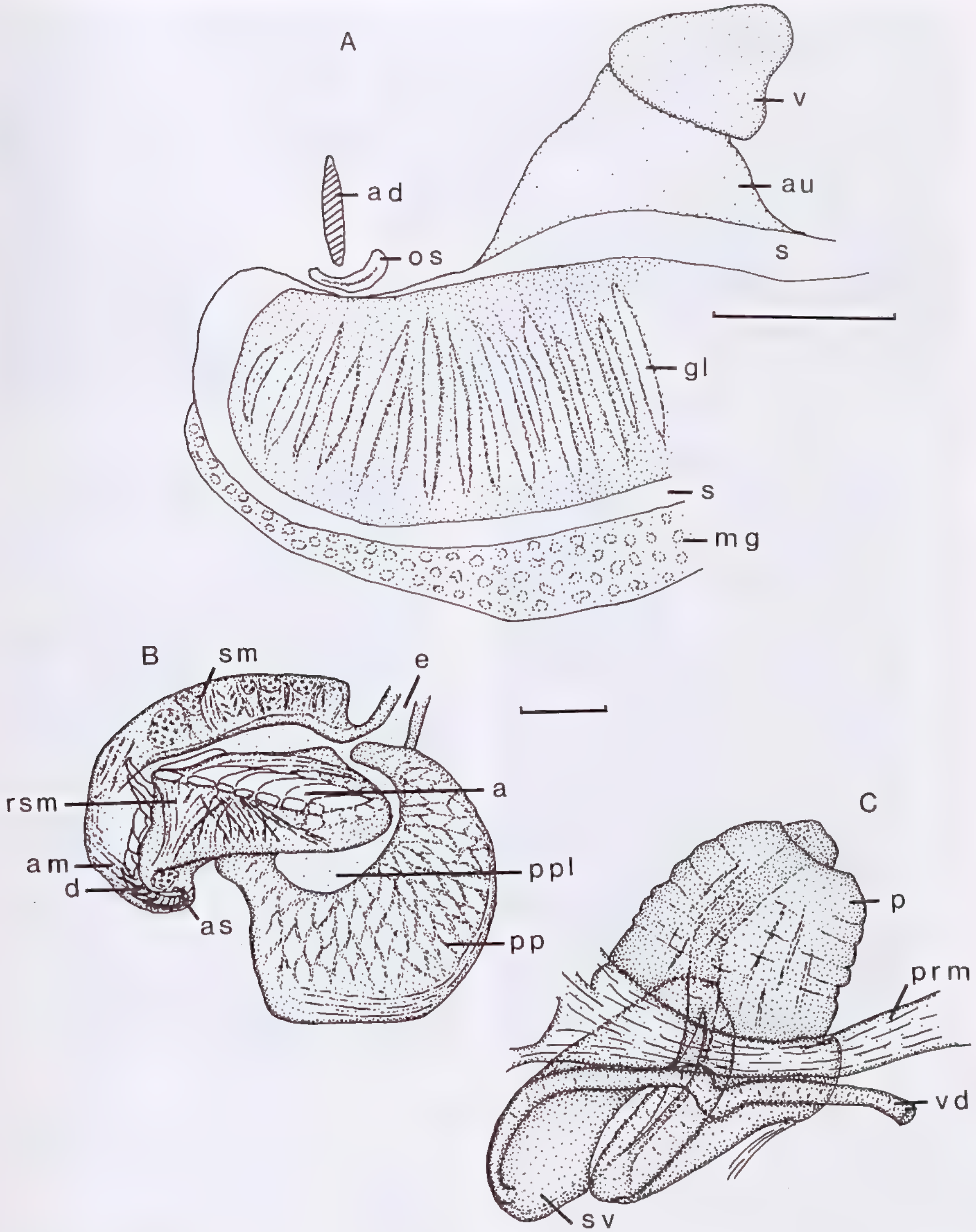

Fig. 4. Anatomy of *Volvatella australis* n. sp. **A**, inner surface of anterior right part of mantle fold. **B**, sagittal section of pharynx. **C**, penis. Scale bars: **A** = 0.5 mm; **B, C** = 0.1 mm. Abbreviations: **a**, ascending limb; **ad**, adductor muscle (cut); **am**, ascus-muscle; **as**, ascus; **au**, auricle; **d**, descending limb; **e**, oesophagus; **gl**, gill lamella; **mg**, mucus glands; **os**, osphradium; **p**, penis; **pp**, pharyngeal pouch; **ppl**, lumen of pharyngeal pouch; **prm**, penis retractor muscle; **rsm**, radula suspending muscle; **s**, sinus; **sm**, dorsal septate muscle; **sv**, seminal vesicle; **v**, ventricle; **vd**, vas deferens.

is the digestive gland. The anus is on a small papilla on top of the digestive gland, approximately mid-dorsally, and just in front of the distinct ventral raphe. At the right anterior corner of the mantle floor is the distinct female genital papilla.

Internal anatomy. The columella muscle divides in the narrow neck, forming anterior and posterior pedal retractors, as well as a strong cephalic retractor muscle; some fibres of the right anterior pedal retractor are confluent with the shell adductor muscle.

The pharynx has a flat dorsal septate muscle. There is a large, muscular pharyngeal pouch about the same size as the pharynx (Figs 3E-F, 4B). The pharyngeal pouch has a double lumen, one side of which is much wider than the other. The pharyngeal complex is located asymmetrically towards the left side of the head. The ascus-muscle is short and thin. The radular teeth are triangular with long, coarse lateral denticles and a hooked tip (Figs 5B-D). The denticles are present at the distal half of the cusp; they are about 2 µm wide and about 5 µm long. A 75 µm tooth had 15 denticles on either side. The radula of a specimen with a shell length of approximately 4 mm had seven fully formed teeth plus one ghost tooth in the ascending limb and 17 plus a rod-shaped preradular tooth in the descending limb, which is positioned almost vertically within the pharynx. The teeth are large compared to the size of the pharynx, and the ascending limb almost fills out the odontophore. The thin-walled oesophagus leaves the pharynx posteriorly and runs on the left side of the pharyngeal pouch. Behind the pharyngeal pouch, the oesophagus penetrates the circum-oesophageal nerve-ring. There is a pair of narrow salivary glands, the posterior ends of which also penetrate the nerve-ring; they enter the pharynx next to the oesophagus. After penetrating the nerve-ring the oesophagus widens, but apparently an actual oesophageal pouch is not formed. This section of the oesophagus has numerous irregular papillae, which may be glandular; behind the widened part the oesophagus has longitudinal folds, and shortly after, it penetrates the diaphragm to the visceral mass. The stomach is small and roughly triangular; it is located on the left anterior side of the visceral mass. The oesophagus enters at the anterior ventral corner; the intestine leaves at the posterior, dorsal corner, and the digestive gland opens on the left side. Branches of the digestive gland enter the infrapallial lobe, and in some specimens branches also enter the dorsal mantle lobe to the left of the pericardium.

In most specimens only mature spermatozoa were found in the gonadal follicles, and the mucus gland (and other female glands) were incompletely developed. The gonad is ventral on the left side, under a thin layer of digestive gland. There is a large, kidney-shaped ampulla filled with spermatozoa. It has not been possible to completely sort out the connections of the reproductive ducts, especially those of the female system. The vas deferens leaves the ampulla antero-ventrally, and has a short prostatic section before penetrating the diaphragm immediately under the female genital papilla. The vas deferens is embedded in the body wall of the cephalic region until shortly before entering the muscular, unarmed penis (Fig. 4C), which is located on the right side of the head, sometimes partly covering the pharynx. The vas deferens has a widening at the base of the penis.

The central nervous system (Fig. 3D) is located postero-ventrally in the cephalic region; the ganglia on the visceral loop are closely attached to the diaphragm, so they are almost impossible to remove intact. The supraintestinal ganglion, located on the right side close to the adductor muscle, sends an osphradial nerve along the adductor muscle to the small osphradial ganglion embedded in the adductor muscle, next to the osphradium. The abdominal ganglion is located where the columella muscle branches into pedal and cephalic retractors; it sends a strong nerve through the diaphragm to the visceral mass. The subintestinal ganglion is on the left side, close to the abdominal ganglion.

Observations on living animals. *Volvatella australis* adheres tenaciously to its substrate; it may retract the central part of the foot sole to create a vacuum. When crawling on a firm substrate, the animals move in a caterpillar fashion, first extending the head-foot, then pulling up the shell and visceral mass.

The habitat at Lee Point is subjected to strong tidal currents running between rocky outcroppings. Most of the *Caulerpa* sp. is attached to the rocks, but some grows in the sand between the rocks. Most specimens of *V. australis* were collected from the assimilators of *Caulerpa* sp., but some, in particular the smaller ones which were not actually seen in the field, may have been hiding in the sediment attached to the rhizoids. In the laboratory *V. australis* seemed

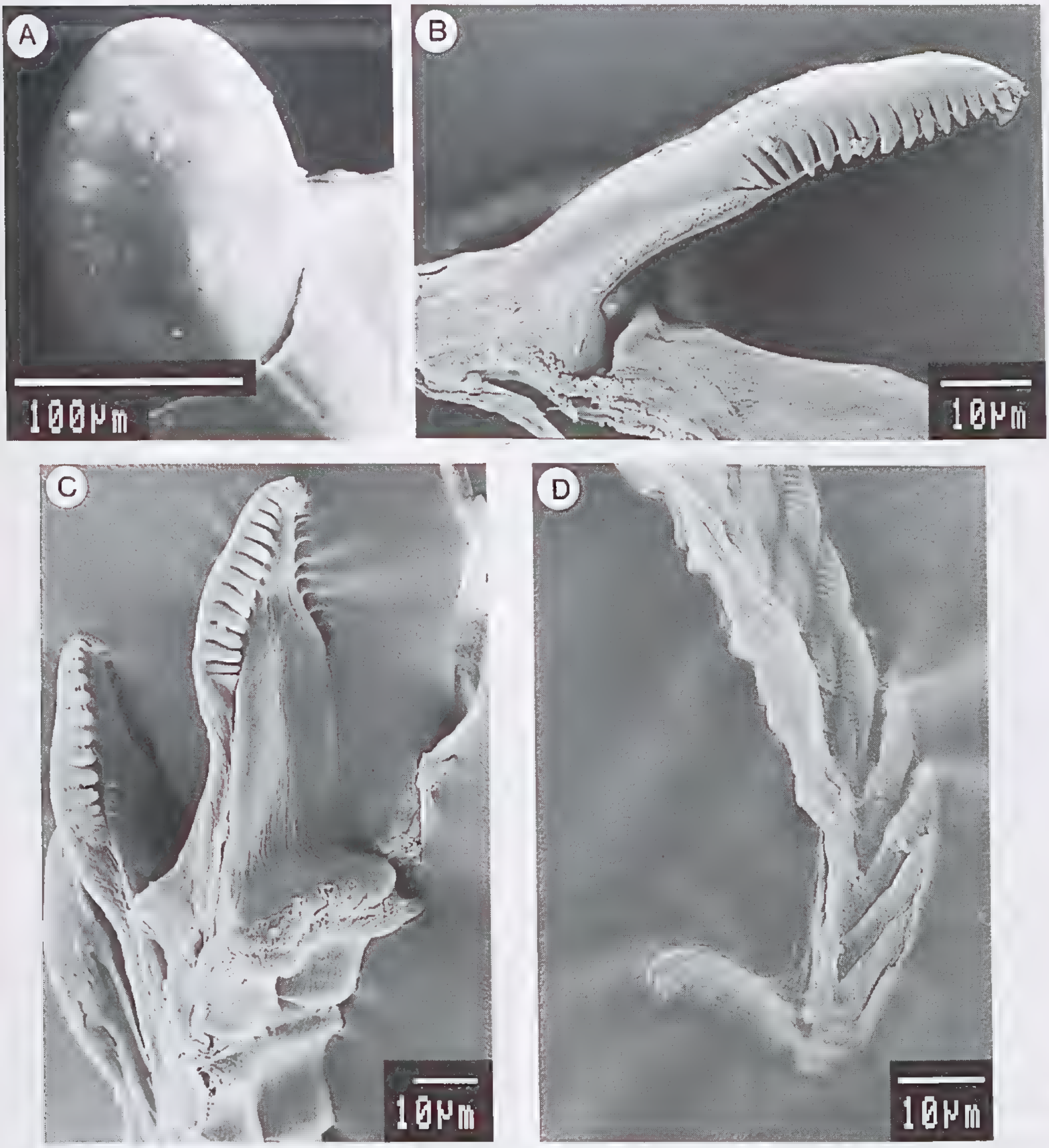

Fig. 5. Scanning electron micrographs of *Volvatella australis* n. sp. **A**, protoconch. **B**, radular teeth, lateral aspect. **C**, radular teeth, latero-frontal aspect. **D**, juvenile teeth and rod-shaped preradular tooth.

to prefer feeding on the rhizoids, which may have thinner cell walls, and possibly fewer internal trabeculae. When feeding, the oral tube is first everted and inflated, then it is deflated and rasping begins. At the same time the head is partly retracted into the shell. The fact that the pharynx must reach out through the everted oral tube may explain its small diameter, and the large size of the pharyngeal pouch, which is probably the most important muscular structure in the feeding process. The animal remains at the same spot for a long time, thus it probably can suck for long distances; unfortunately there is very little green material in the rhizoids, so movement of cell sap could not be followed. The feeding of *V. australis* leaves a small, but distinct, hole in the cell wall of *Caulerpa* sp.

A small specimen was often seen "riding" on the shell of a larger specimen (Fig. 1). Apparently the small specimen was waiting for an opportunity to copulate. During copulation the animals usually face in the same direction. The penis can be greatly extended, but only the tip is actually inserted through the female genital pa-

Table 1. Characters of previously described species of *Volvatella.*

Nomenclature	Colour of mantle	Shell spout	Penial stylet
1. *V. fragilis* Pease, 1860	white	long	?
2. *V. cumingi* (A. Adams 1850) as *Bulla*	?	long	?
3. *V. vigourouxi* (Montrouzier, 1861)	white, (with orange ?)	long	present
4. *V. candida* Pease, 1868	white	very short	?
5. *V. pyriformis* Pease, 1868	orange, with red spots	short	?
6. *V. cincta* G. and H. Nevill, 1869	orange, with red spots	medium	?
7. *V. laguncula* Sowerby, 1894	white	short	absent
8. *V. omega* (Melvill, 1918) as *Oxynoe*	?	very short	?
9. *V. kawamurai* Habe, 1946	brown?	long	(present ?)
10. *V. elioti* (Evans, 1950) as *Arthessa*	?	long	?
11. *V. evansi* (Kay, 1961) as *Arthessa*	orange, with red spots	short	?
12. *V. ficula* Burn, 1966	white, with orange bands	short	absent
13. *V. ayakii* Hamatani, 1972	white	short	absent
14. *V. viridis* Hamatani, 1976	green	short, skewed	absent
15. *V. bermudae* Clark, 1982	green	short, skewed	present
16. *V. ventricosa* Jensen and Wells, 1990	green	short, skewed	present
17. *V. angelinianae* Ichikawa, 1993	white, w. orange bands	long	?

pilla. If sizes are widely differing, copulation is not reciprocal.

Discussion. Seventeen species of *Volvatella* have been described (Table 1). Two species, *V. laguncula* and *V. ayakii*, are very similar to the present new species. In the former the mantle is uniformly covered by small white dots, completely obscuring the underlying visceral mass. The head appears very large compared to the body (Thompson 1979; Gosliner 1987). *V. ayakii* is the species most closely resembling *V. australis*. The radular teeth of *V. ayakii* may be slightly broader, the denticles shorter and more numerous (Hamatani 1972). Glandular bosses along the posterior mantle edge were not mentioned for *V. ayakii*, but have been described in *V.* cf. *vigourouxi* (Baba 1966). In *V. ayakii* the reflected inner lip forms a short sutural keel along the shell spout; this is not found in *V. australis*. Also, there are no branches of the digestive gland entering the mantle fold of *V. ayakii*.

Earlier many species with similar external morphology have been synonymized (e.g. Clark 1982). However, the fact that reproductive anatomy, especially penial morphology, varies, as does development type, indicates that there are several groups of sibling species. Synonymy cannot be determined until the anatomy of all species has been examined. Unfortunately no figure exists of the penis of either *V. ayakii* or *V. laguncula*, the two species most closely related to *V. australis*.

Etymology. The specific name *australis* refers to the occurrence of this species in Australia.

Family Juliidae E.A. Smith, 1885

This family comprises the bivalved Sacoglossa. Two genera are presently recognized, *Julia* and *Berthelinia*. The latter may be subdivided into a number of subgenera, but the delimitation of these is not completely unequivocal.

Genus *Berthelinia* Crosse, 1875

A definition of this genus can be found in Jensen (1993a). The structure previously referred to as the "hypobranchial gland" (Baba 1961; Kay 1964; Jensen 1993a) is in fact homologous to the dorsal and ventral raphes ("ciliated bands") of other Heterobranchia (Ponder 1991). This is clearly seen in live specimens where ciliary activity can be seen especially well on the tall ventral raphe. The fact that these raphes are accompanied by bands of glands, which secrete a white mucus upon disturbance of the animals has led to the designation of this complex as a hypobranchial gland, but it is not homologous to that structure in the Prosobranchia.

Berthelinia darwini n. sp.

Type material. HOLOTYPE - NTM P6969, shell length 2.5 mm, Lee Point, on *Caulerpa* spp., 20 July 1993, coll. K.R. Jensen. PARATYPE - 1 specimen (ZMUC), shell length 3.5 mm, East Point, 12 July 1993, coll. P. Hutchings.

Other material. 3 specimens (1 dissected) on *Caulerpa* spp. collected by P. Hutchins, East Point, 12 July 1993; 5 specimens (4 dissected) on *Caulerpa* spp., collected by K.R. Jensen, Lee Point, 20 July 1993.

Description. *Shell.* The shell (Fig. 7A) of the largest specimen was about 4.5 mm long. The protoconch (Figs 7B, 9A) is almost horizontal in the larger specimens, more upright in smaller specimens, and about 200 µm long. The protoconch is located just anterior to the posterior third of the shell length (range 0.55-0.68, n=8). The shell is roughly elliptical, broadest anteriorly. It is rounded anteriorly as well as posteriorly, and not particularly narrow posteriorly. Shell height is about two-thirds of shell length (range 0.59-0.68, n=8). The periostracum is yellowish, slightly overhanging the shell.

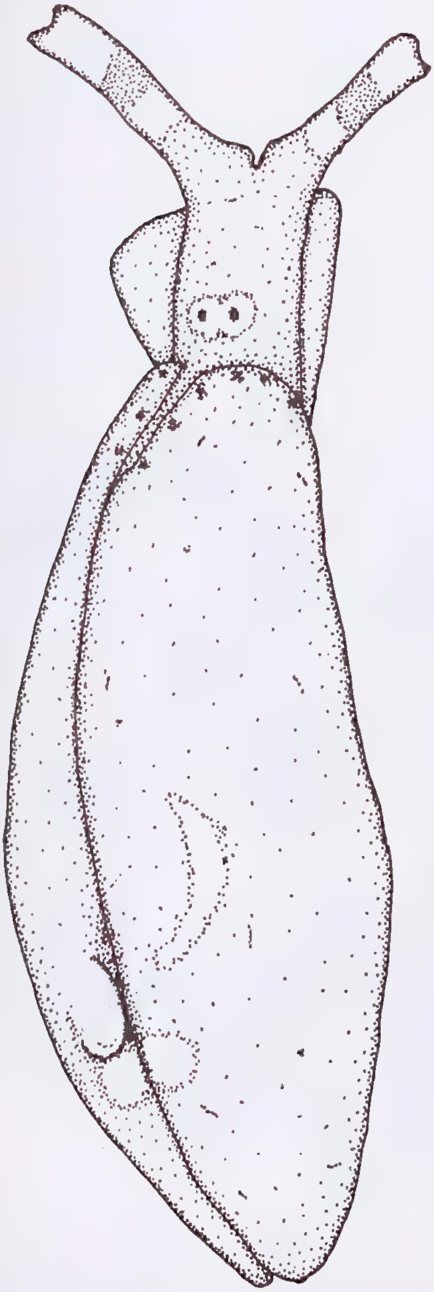
Fig. 6. *Berthelinia darwini* n. sp. Live animal drawn from colour slide by K.R. Jensen. Shell length ca. 4.5 mm.

Colour alive. The specimens from East Point were grass green whereas those from Lee Point were much paler green, almost transparent. The tips of the rhinophores are white, and white mottlings are also scattered on head and mantle. Brown pigment is scattered on mantle of grass green animals, and along mantle margin, alternating with white in both colour-forms. The foot sole is lighter coloured in the grass green specimens.

External features (Figs 6-7). The rhinophores are grooved all through their length; the medial fold continues to the oral lobes. The eyes are on a small protuberance behind the rhinophores. The foot folds longitudinally when the animal is suspended from the surface film. The anterior foot corners are rounded, forming distinct pedal lobes separated by a median notch. The penial opening is behind and slightly ventral to the eyes, immediately above the ciliated spawn groove, which runs from the opening of the female genital papilla to the mouth area on the right side.

Pallial organs. The gill of a specimen with a shell length of 4 mm had 35 lamellae. There is a small osphradium close to the adductor muscle. The upper raphe (Fig. 7C), posterior to the gill, is fairly low; the lower raphe, on the surface of the visceral mass, behind the intestine, is high. Both raphes are accompanied by glands on either side of the ciliated band (Figs 7C-D). The anus opens on a low papilla just in front of the lower raphe and fairly close to the ventral edge of the visceral mass (Fig. 7D). The female genital papilla is located anterior to the intestine and opens anteriorly at the beginning of the ciliated spawn groove.

Internal anatomy. The pharynx (Fig. 8A) is large and asymmetrical. The dorsal septate muscle is thin. The radular sac protrudes posteriorly. The ascus-muscle is thick anteriorly and free posteriorly.The salivary glands are large, but they usually break apart when the pharynx is removed. The paired pharyngeal pouches are rather short and open next to the opening of the oesophagus. The oesophagus is narrow anteriorly. There is a large, thin-walled oesophageal pouch with low papillae (glandular?) on the inner surface. Behind the oesophageal pouch, the oesophagus is broad and flat. It passes into the visceral mass below the adductor muscle. The radular teeth (Fig. 9C-D) are blade-shaped with fine lateral denticles and pointed tips. The teeth in the ascus are spirally coiled in the largest specimens. The radula of a specimen with a shell length of 4 mm had seven fully formed teeth plus one ghost tooth in the ascending limb, 24 in the descending limb, and about

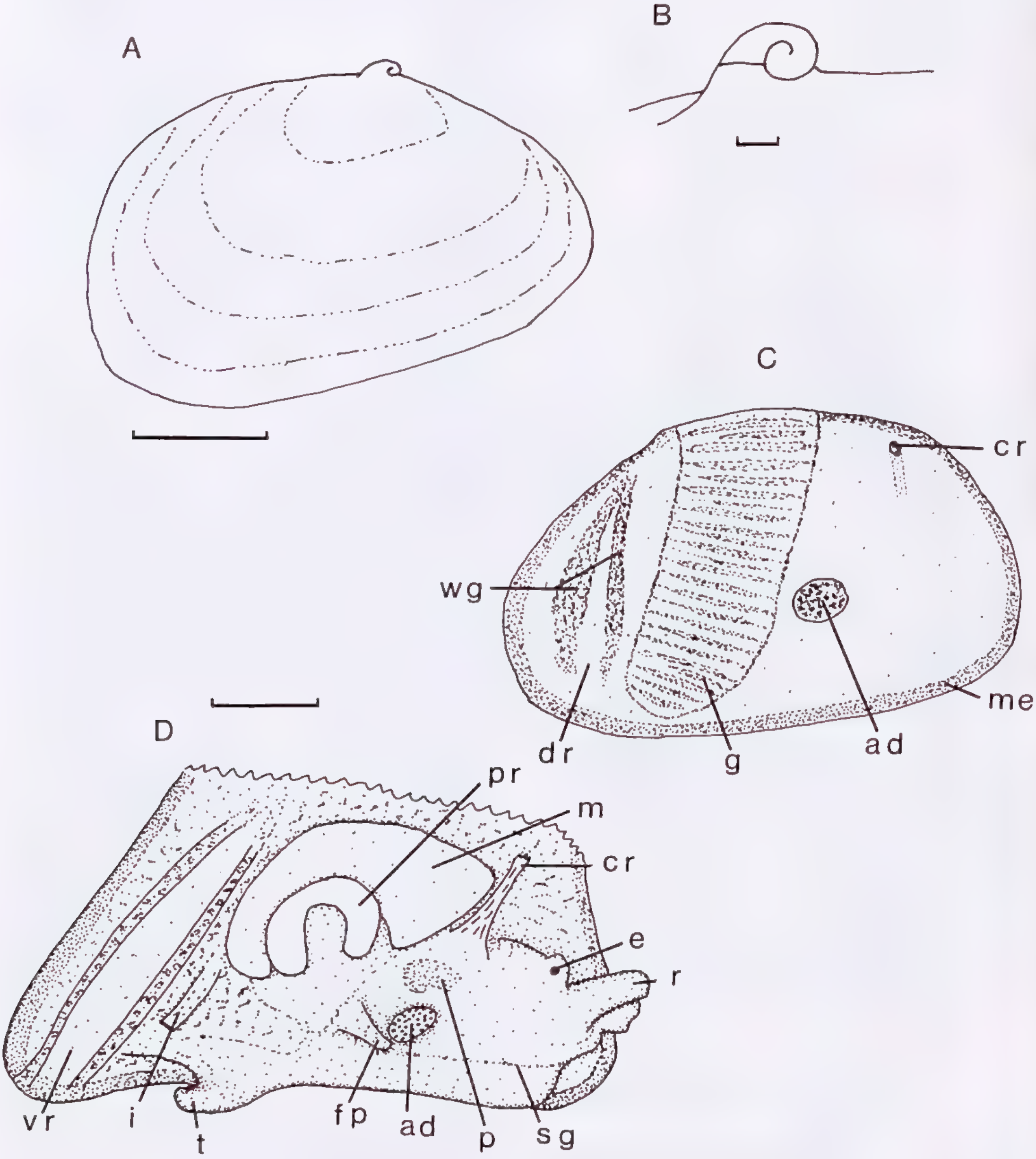

Fig. 7. *Berthelinia darwini* n. sp. **A**, outline of shell. **B**, close-up of protoconch. **C**, surface of mantle fold. **D**, external view of preserved specimen after removal of shell and mantle fold. Scale bars: **A** = 1 mm; **B** = 0.1 mm; **C, D** = 0.5 mm. Abbreviations: **ad**, adductor muscle (cut); **cr**, cephalic retractor muscle; **dr**, dorsal raphe; **e**, eye; **fp**, female genital papilla; **g**, gill; **i**, intestine; **m**, mucus gland of the female reproductive system; **me**, mantle edge; **p**, outline of penis; **pr**, prostate; **r**, rhinophore; **sg**, spawn groove; **t**, tail; **vr**, ventral raphe; **wg**, white mucus glands.

10 teeth, plus the rod-shaped preradular tooth (Fig. 9D), coiled up in the ascus; a specimen with a shell length of 3 mm had six teeth in the ascending limb and 30 teeth in the descending limb, plus the rod-shaped preradular tooth; a specimen with shell length 2.5 mm had seven teeth in the ascending limb and 20 in the descending limb, plus the preradular tooth. It should be noted that the fine, lateral denticles cover a relatively shorter part of the tooth in the small, juvenile teeth than in the larger, adult teeth. Also, a few teeth in the spiral ascus have bifid tips (Fig. 9D).

The central nervous system is similar to that of *B. limax* (Baba 1961), except that the supraoesophageal ganglion is closer to the cerebro-pleural ganglion.

The penis in preserved specimens is folded up just above the adductor muscle. There is a long, coiled, flexible penial stylet (Fig. 9B). From the ventral surface of the female genital papilla a ciliated duct extends to the ventral genital receptacle; just behind the female genital papilla is a small, sperm-filled vesicle, which is probably the functional bursa copulatrix (Fig. 8B). It is apparently connected to the duct of the genital receptacle. The mucus gland is strongly folded; the folds are ciliated. The hermaphroditic ampulla is found ventrally on the left side; it is a slightly coiled, widened part of the hermaphroditic duct. The vas deferens widens to form a curved prostatic section on top of the mucus gland. From the ventral part of the prostate the vas deferens runs anteriorly immediately beneath the female genital papilla. Inside the cephalic hemocoele the vas deferens is free. The small oviduct enters the mucus gland ventrally. It was not possible to discern the connection of the albumen gland, which is closely applied to the medial and ventral surface of the mucus gland. Nor was a fertilization region identified. The large oviduct leaves the mucus gland very close to the entrance of the small oviduct, so the pathway of the eggs inside the mucus gland must be U-shaped (up and down all the ciliated folds).

Observations on living animals. When feeding on *Caulerpa* sp., the oral tube is partly everted and inflated. The backwards movement of the pharynx is most forceful, indicating "cutting" action of the radular teeth (Jensen 1993b). The head expands laterally during the forwards movement during rasping. It appears that the animals rasp continuously, and intermittently, a small mouthful of cytoplasm is swallowed. When the cell wall is first penetrated, and again when feeding is completed, the shell pivots, and the head is completely withdrawn into the shell. The animals feed for a long time (>20 min) at the same spot. Immediately after feeding, a round

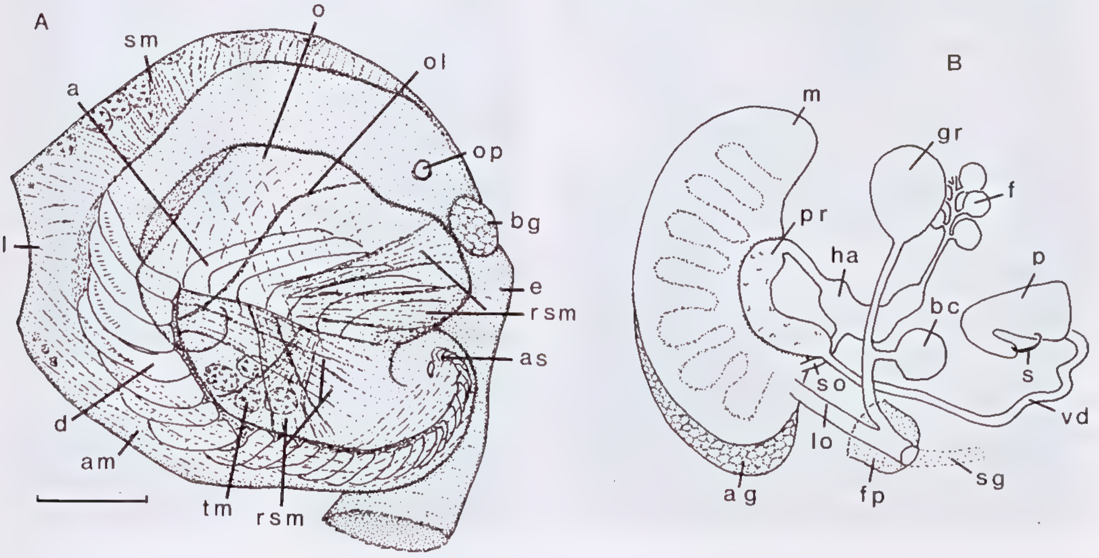

Fig. 8. Anatomy of *Berthelinia darwini* n. sp. **A**, sagittal section of pharynx. Scale bar = 0.1 mm. **B**, schematic drawing of reproductive system. Abbreviations: **a**, ascending limb; **ag**, albumen gland; **am**, ascus-muscle; **as**, ascus; **bc**, bursa copulatrix; **bg**, buccal ganglion; **d**, descending limb; **e**, oesophagus; **f**, hermaphroditic follicles; **fp**, female genital papilla; **gr**, genital receptacle; **ha**, hermaphrodite ampulla; **l**, pharyngeal lips; **lo**, large oviduct; **m**, mucus gland; **o**, odontophore; **ol**, lateral attachment of odontophore; **op**, opening of pharyngeal pouch; **p**, penis; **pr**, prostate; **rsm**, radula suspending muscles; **s**, penial stylet; **sg**, spawn groove; **sm**, dorsal septate muscle; **so**, small oviduct; **tm**, transverse muscles; **vd**, vas deferens.

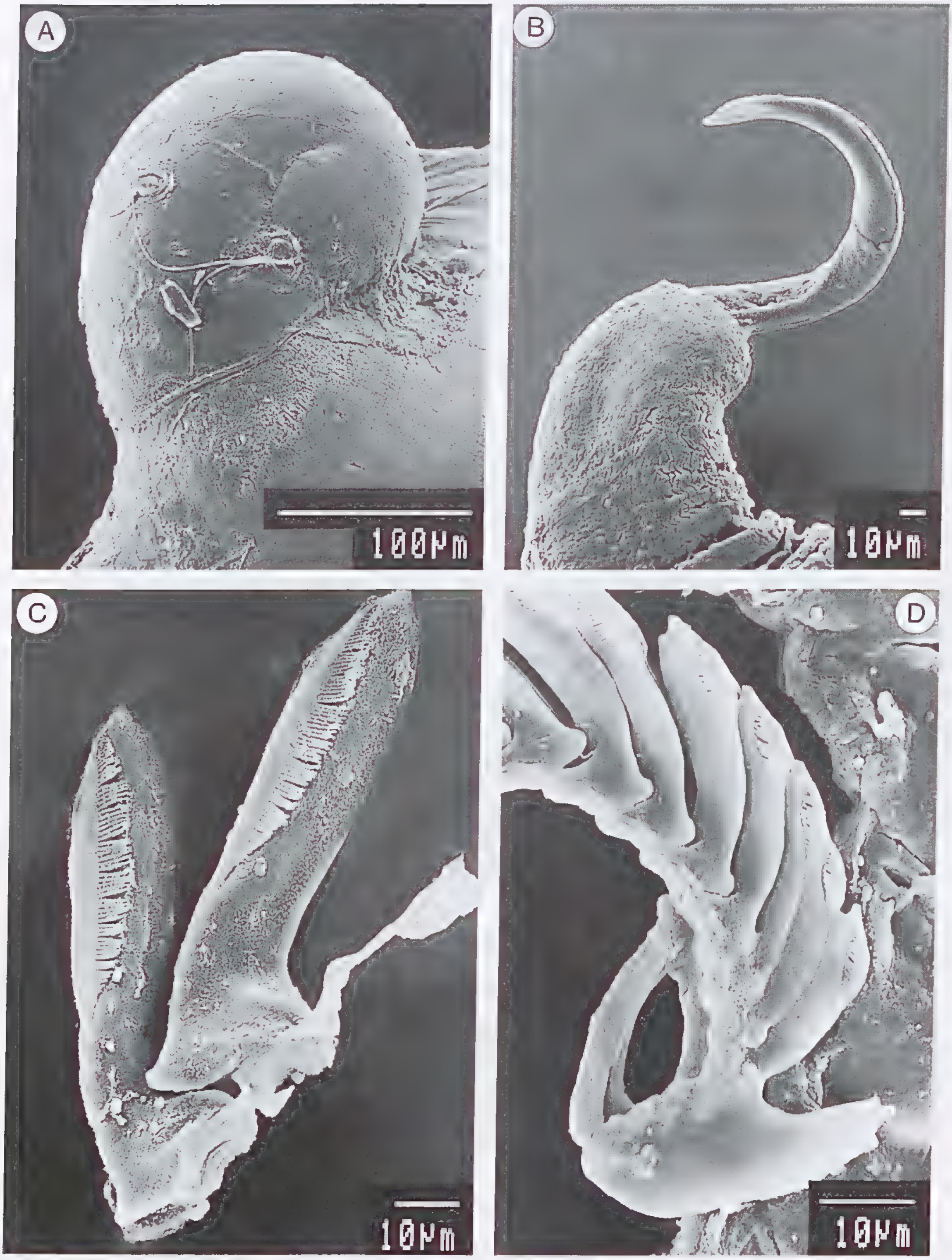

Fig. 9. Scanning electron micrographs of *Berthelinia darwini* n. sp. **A**, protoconch. **B**, penial stylet. **C**, radular teeth. **D**, juvenile teeth and rod-shaped preradular tooth.

or irregularly shaped hole is seen in the algal cell wall; later a white ring with more or less radiating fine lines appears around the hole. The large size of the incision in the cell wall is not consistent with a "cutting" action of the teeth, unless the cell wall is cut several times at slightly different angles in the same spot.

When copulation begins, the penis is everted suddenly. The flexible stylet is housed inside the tip of the penis and is inserted corkscrew-wise into the female genital papilla during intromission. The penis is inserted into the mantle cavity ventrally under the right valve, and the animals are usually facing in the same direction. A copulation bout, possibly consisting of several consecutive intromissions, may last two hours. In non-reciprocal copulations, the "female" partner may continue feeding during copulation.

During copulation, the valves are kept slightly apart, and it is then possible to observe the ciliary currents within the mantle cavity. The mantle edge makes rhythmic contractions; also the gill lamellae and the anus contract and expand periodically. Ciliary activity is high on the dorsal and ventral raphes, possibly accompanied by mucus secretion.

Discussion. Externally, *Berthelinia darwini* is similar to *B. babai* (Burn, 1965), *B. limax* (Kawaguti and Baba, 1959), *B. fijiensis* (Burn, 1966), *B. ganapati* Sarma, 1975, and *B. schlumbergeri* Dautzenberg, 1895. However, anatomically it is quite distinct from any of these species for which anatomy has been described. The external similarity of several species of *Berthelinia* (Gosliner 1987; Jensen 1993a), and also the variability in shell shape noted for several species (Edmunds 1963; Jensen 1993a), including *B. darwini*, make it impossible to designate synonymy for these species. Only the species for which anatomy has been described can be compared. Differences in penial anatomy serve to ensure reproductive isolation and are therefore considered very important in describing the present specimens as a distinct species. Penial armature has only been described for two bivalved sacoglossans. *Berthelinia (Edenttellina) typica* (Gatliff and Gabriel, 1911) has a stylet very similar to that of the present species, except that there is a small basal spur (Gascoigne 1974). *Berthelinia (Midorigai) australis* (Burn, 1960) has a straighter stylet with a subterminal flange (Gascoigne 1974). The teeth of *B. typica* are smooth and have bifid tips; the teeth of *B. australis* have rather coarse lateral denticles and a simple tip. The relatively large protoconch of *B. darwini* indicates direct development, and a small, lenticular egg mass deposited on July 20 contained only 15 eggs singly within large capsules. Unfortunately development to hatching could not be followed.

Etymology. The specific name *darwini* refers to the type locality, Darwin Harbour.

Family Limapontiidae Gray, 1847

Limapontiidae Gray, 1847.

Stiligeridae Iredale and O'Donoghue, 1923

Studies on the reproductive systems of the cerata-bearing Sacoglossa have shown that the genus *Limapontia* belongs in the family Stiligeridae (Gascoigne 1976, 1985). However, the oldest family name, then, is not Stiligeridae but Limapontiidae. Recent cladistic analysis has shown that the cerata-bearing genera form one monophyletic superfamily, Limapontioidea, and that the genus *Costasiella* clustered among the genera of the Limapontiidae, rendering the family Costasiellidae Clark, 1984, superfluous (Jensen 1996).

Genus *Costasiella* Pruvot-Fol, 1951

Species of *Costasiella* are generally small (<7 mm). They have simple rhinophores, sometimes with a basal "flap", sometimes basally grooved. The most distinctive character is that the eyes are located between the rhinophores, close together; the eyes are usually big. Some species have prolonged pedal tentacles and/or the tail distinctly set off, mimicking the shape of a ceras. The cerata of most species have narrow, glandular tips. The pericardium is tall and large. Many species have a pharyngeal pouch, and the radular teeth are blade-shaped with a smooth cutting edge. They have a long, usually unarmed penis. In some species the albumen gland enters the cerata. A separate family, Costasiellidae Clark, 1984, was created because the reproductive system is neither "hermaeid" nor "stiligerid" (*sensu* Gascoigne 1976). Almost all species have been collected from *Avrainvillea* spp.

Costasiella mandorahae n. sp.

Type material. HOLOTYPE - NTM 6971, 2 mm long preserved, rock platform north of Mandorah, on *Avrainvillea* sp., K.R. Jensen, 10 July 1993. PARATYPES - 3 specimens (2 dissected) (ZMUC), 1 mm, 1.6 mm, 1.7 mm, same data as holotype.

Other material. 3 specimens, same data as holotype.

Description. *Colour alive.* This species is very lightly coloured. On the anterior surface of the head is a median orange stripe (Fig. 10). In some specimens there are also thin orange stripes along the antero-lateral ridges of the head. The rhinophores are transparent, with a few rust-coloured dots; in some specimens these dots are arranged in a longitudinal stripe on the dorsal surface. Behind the black eyes is a coloured spot. The arrangement of rust-coloured and orange dots varies among specimens. Usually there are two rust-coloured spots anteriorly and a transverse rust-coloured band just in front of the pericardium; these spots are connected by a dark orange spot. The cerata have white tips and a subterminal orange band or spot. A few iridescent blue dots are found on the cerata. Orange dots are scattered on the pericardium, and in some specimens also on the dorsal surface of the tail. The main part of the body and cerata is green from the contents of the digestive gland. Ventrally a black stripe, corresponding to the hermaphrodite ampulla, is visible through the foot sole.

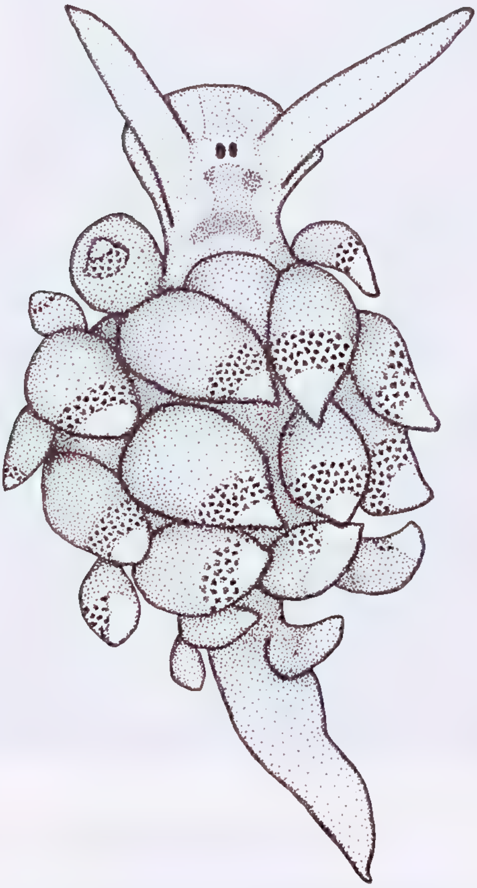

Fig. 10. *Costasiella mandorahae* n. sp. Live animal drawn from colour slide by K.R. Jensen. Total length of animal ca. 5 mm.

External features. The present specimens were up to 5 mm long alive. The anterior surface of the head is flat with distinct antero-lateral ridges (Fig. 10). There are no oral tentacles, and no median notch is found (Fig. 11A-B). The rhinophores are simple or flattened with a short basal groove ventrally, but no basal "flap". The eyes are located between the rhinophores, close together. The cerata are fusiform or slightly inflated with a narrow tip. The pericardium is tall and rounded (Fig. 11C). No dorsal vessels were seen in the present specimens. The anus is on a small papilla to the right of and anterior to the pericardium, in front of the first ceras. Tubules of the digestive gland appear to radiate towards the cerata from the pericardial region. The anterior foot corners are rounded. The tail is set off from the anterior foot sole by a distinct constriction (Fig. 11A-B), giving it a strong similarity to a ceras. The penial opening is below the right rhinophore and the female opening is close behind this. On the left side is another conspicuous opening below the second row of cerata (Fig. 11B); this is an opening to the genital receptacle.

Internal anatomy. The pharynx is small, but it has a distinct muscular pouch (Fig. 12B). The ascus-muscle is posteriorly free. The radular teeth are blade-shaped with smooth edges (Fig. 13A) and uniform in size (approx. 34 mm). The radula of a 1.6 mm specimen (preserved length) had seven teeth plus a "ghost" tooth in the ascending limb, seven teeth in the descending limb, and a heap of densely packed teeth in the ascus. There is a large, spherical oesophageal pouch. The digestive gland in the cerata forms a dense layer of spherical branchlets (Fig. 12A), giving a reticulate pattern to the cerata. Similar branchlets of digestive glands are found in the "base" of the tail.

The penis is elongate and without a stylet (Fig. 12C). It has an inner layer of circular muscles, which also surround the vas deferens, and an external layer of longitudinal muscles. The prostate is composed of three elongate lobes lying underneath the small mucus gland. There is a small seminal receptacle containing oriented sperm. The albumen gland does not enter the cerata. The hermaphrodite ampulla is wide and coiled. There are relatively few hermaphroditic follicles (three to four on each side). Due to the small size of the animals, it has not been possible to identify the connections of the various parts of the female reproductive system. An important feature, however, is the presence of a separate opening of the genital receptacle on the left side.

The ganglia of the highly concentrated circumoesophageal nerve-ring are almost bigger than the pharynx. Apparently there are only two visceral ganglia, but this is difficult to see because of the small size and almost non-existent connectives.

Spawn. The egg mass is a regular spiral with only two eggs across the ribbon. An egg mass containing 160 eggs had 4½ whorls. Another egg mass containing 145 eggs had 3½ whorls. Veligers from the latter egg mass hatched after five days, so development is probably plankto-trophic.

Copulation. Copulation is "head to head". The penis is partly everted before the animals actually touch; animals then test one another for

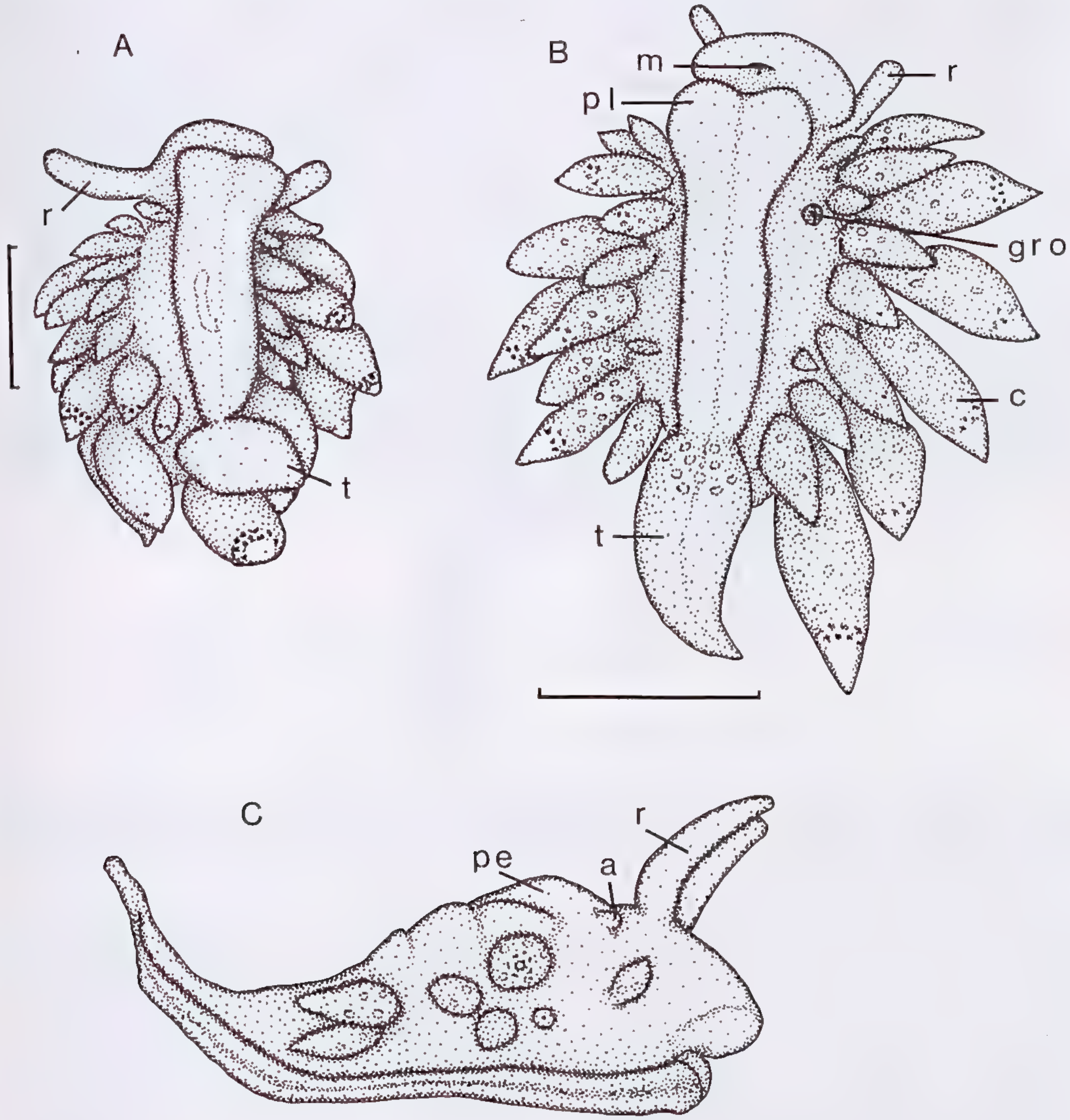

Fig. 11. A, ventral view of preserved *Costasiella mandorahae* n. sp. **B**, latero-ventral view of preserved *Costasiella mandorahae* n. sp., left side. **C**, lateral view of preserved *Costasiella mandorahae* n. sp. after removal of most cerata, right side. Scale bars = 0.5 mm. Abbreviations: **a**, anal papilla; **c**, ceras; **gro**, opening of genital receptacle; **m**, mouth; **pe**, pericardium; **pl**, pedal lobe; **r**, rhinophore; **t**, tail.

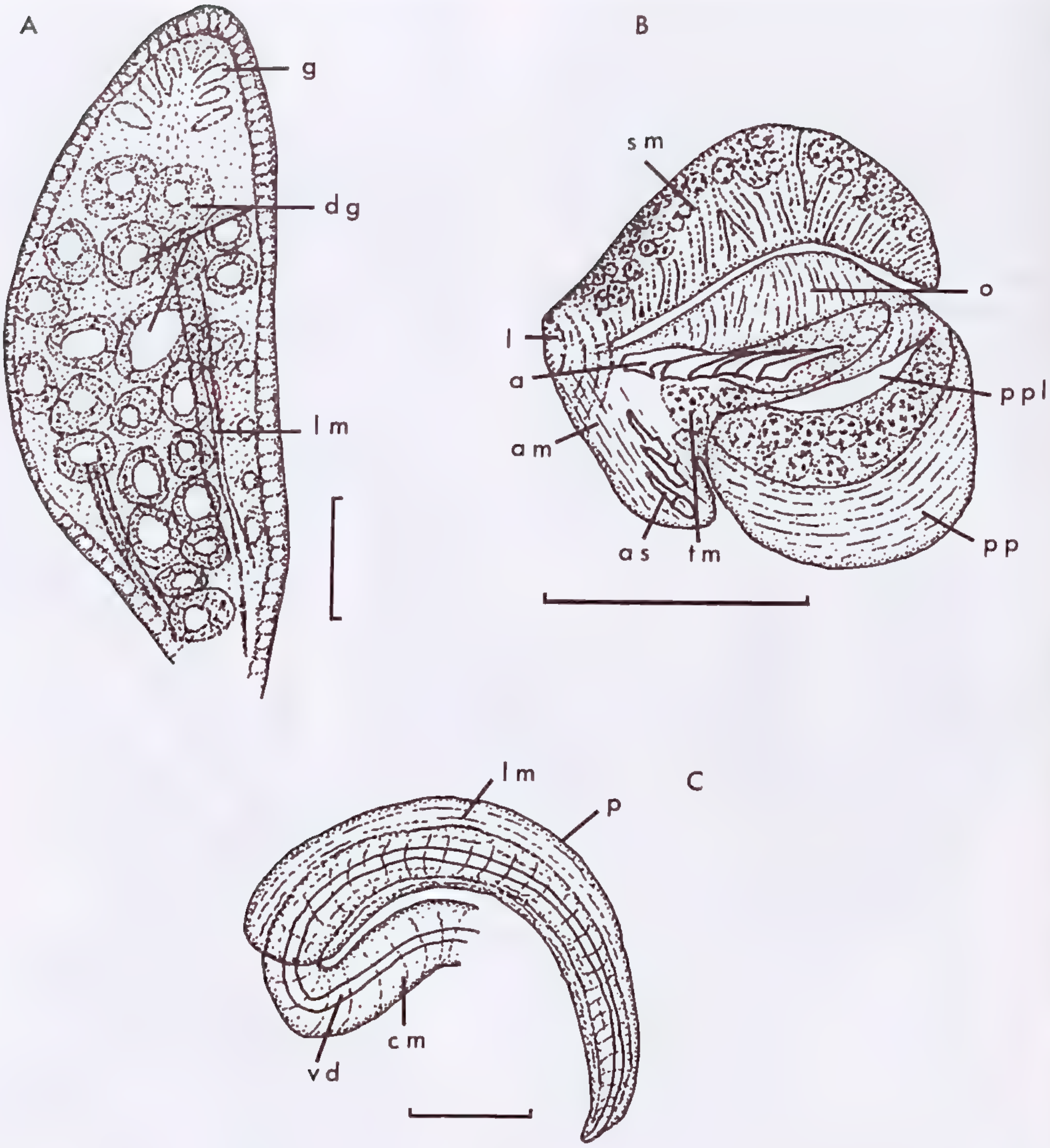

Fig. 12. Anatomy of *Costasiella mandorahae* n. sp. **A**, longitudinal section of ceras. **B**, sagittal section of pharynx. **C**, penis. Scale bars = 0.1 mm. Abbreviations: **a**, ascending limb; **am**, ascus-muscle; **as**, ascus; **cm**, circular muscles; **dg**, digestive gland tubes; **g**, subepidermal glands; **l**, pharyngeal lips; **lm**, longitudinal muscles; **o**, odontophore; **p**, penis; **pp**, pharyngeal pouch; **ppl**, lumen of pharyngeal pouch; **sm**, dorsal septate muscle; **tm**, transverse muscles; **vd**, vas deferens.

some time before actual copulation. The female genital opening is very close to the penial opening. Copulation is very fast, lasting about 1 minute.

Discussion. Ichikawa (1993) described six species of *Costasiella* from southern Japan. However, these descriptions appear to be based more on colour photographs than on actual specimens; only colour pattern and dorsal morphology were described. Shape of the pericardium, presence of dorsal vessels, position of anus and genital openings, which are all important for identifying species of this genus (Marcus 1982), are not mentioned, and internal anatomy is not described at all, not even radular teeth. Hence it is impossible to recognize any of these species, several of which are probably synonymous, and possibly include the present species. However, it is deemed necessary to create a new taxon as it is not possible to make a certain identification

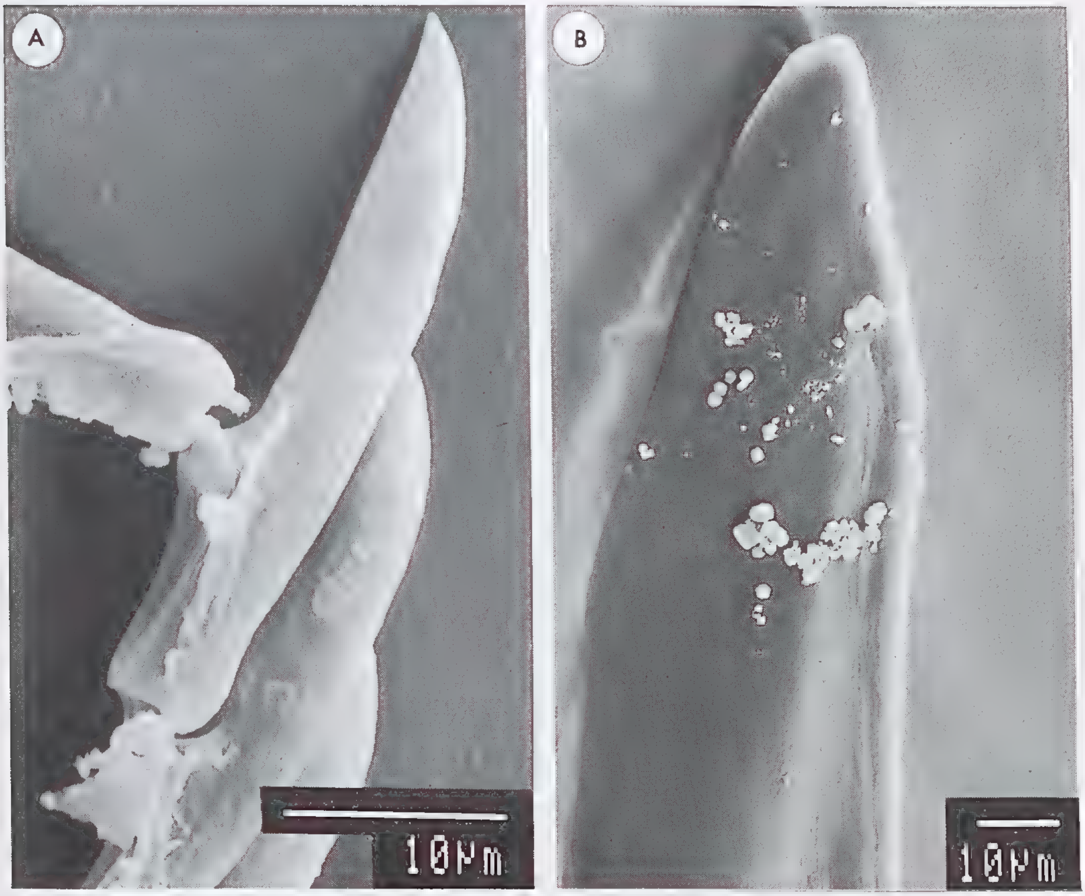

Fig. 13. Scanning electron micrograph of radulae of sacoglossans from the Darwin Harbour area. **A**, radular teeth of *Costasiella mandorahae* n. sp. **B**, tip of radular tooth of *"Stiliger" smaragdinus*.

of the present specimens with any of the Japanese species. *C. mandorahae* is most similar to *C. kuroshimae* Ichikawa, 1993, but lacks black tips of the rhinophores. Also, the rhinophores of *C. mandorahae* are grooved basally; this was not mentioned for *C. kuroshimae*. Further, *C. mandorahae* has an orange ring or spot subterminally on the cerata, and the tail is separated from the anterior foot sole by a constriction. Again, this was not mentioned for *C. kuroshimae*. *C. mandorahae* also shows some similarity to *C. vegae* Ichikawa, 1993, and *C. rubrolineata* Ichikawa, 1993, but lacks ocellate spots and has iridescent dots only on the cerata. *C. illa* (Marcus, 1965) has a basal "flap" on the rhinophores. A separate opening of the genital receptacle has been described in the Caribbean *C. ocellifera* (Simroth, 1895) (= *C. lilianae* (Marcus and Marcus, 1969)) (Gascoigne 1979; Clark 1984). This species differs in colouration and also it has branches of the albumen gland in the cerata (Marcus 1982).

Etymology. The specific name *mandorahae* refers to the type locality, Mandorah in Darwin Harbour.

Genus *Stiliger* Ehrenberg, 1831

Many species presently referred to this genus probably belong to several different, mostly undescribed, genera. Although the type species has not been recollected from the type locality, a sufficient number of species, obviously closely related to the type species, have now been studied anatomically (Baba and Hamatani 1970; Ortea 1981; Jensen 1993a) to define the genus (Jensen 1993a). It has been noted previously that the species originally described as *Stiliger smaragdinus* by Baba (1949) does not belong in the genus *Stiliger* (Baba and Hamatani 1970; Burn 1972; Jensen 1993b; Ichikawa 1993). A description of a new genus is currently being prepared by the present author in collaboration with R. Burn.

"Stiliger" smaragdinus Baba, 1949

"Stiliger" smaragdinus Baba, 1949.

Stiliger (Ercolania) smaragdinus Baba, 1959.

Hermaeina smaragdina Baba and Hamatani, 1970.

Aplysiopsis cf. *smaragdina* Burn, 1972.

Ercolania smaragdina Ichikawa, 1993.

Material examined. 1 specimen, South Shell Island, on *Caulerpa* spp., 8 July 1993, K.R. Jensen; 2 specimens on *Caulerpa* spp. coll. by G. Edgar, East Arm, 8 July 1993; 1 specimen, Lee Point, 20 July 1993, coll. K.R. Jensen.

Comparative remarks. The species has recently been described anatomically. However, the present specimens differed somewhat from specimens collected from Rottnest Island, Western Australia (Jensen 1993a): the tips of the rhinophores were slightly tapering instead of blunt; there was no dark stripe in the neck region, only a white one. The glands at the tip of the cerata formed a distinct knob. In the largest specimen (length 15 mm preserved) the largest cerata were flattened in the preserved specimen.

As the present specimens were larger than those from Rottnest Island, it has also been possible to add some information on the anatomy, especially of the reproductive system. The inner surface of the rolled rhinophores is strongly folded. The oral lobes are deeply grooved or folded, though not forming distinct tentacles. The radular teeth (Fig. 13B) are blade-shaped with denticulate edge. The inside of the cerata is crammed full of tubules of the digestive gland. The separation of the two lobes of the mucus gland was not as distinct as in the smaller Rottnest Island animals, probably due to greater development of glandular portions in the present specimens. The hermaphrodite duct entered the long, bent ampulla rather far anteriorly; thus apparently the ampulla is not entirely a widened part of the hermaphrodite duct. In the largest specimen, the proximal part of the vas deferens was surrounded by glands; this was in addition to the large, lobular gland found in the smaller specimens, and previously interpreted as the prostate gland. Also, in this specimen, which had spawned in the laboratory, the seminal receptacle was almost empty.

Spawn. One animal produced two egg masses, and egg masses were also collected in the field. The egg mass forms an irregular spiral. The eggs are densely crammed within the egg mass. The embryos are rather large compared to the capsules. Prior to hatching, the larvae had a dark spot on the right side, which may be the larval kidney or/and the melanin-black vesicle.

Discussion. As a description of a new genus for this species is in progress, a discussion of the species will be deferred until then. A discussion may be found in Jensen (1993b).

Genus *Ercolania* Trinchese, 1872

A generic definition has been given in Jensen (1993a). Several characters vary among species, and it may be necessary to split the genus when more species are examined anatomically.

Ercolania translucens Jensen, 1993

Material examined. 5 specimens on fine filamentous green algae (*Cladophora* sp. and *Rhizoclonium* sp.) collected at Ludmilla Creek, 12 July 1993, coll. K.R. Jensen. 3 specimens from filamentous algae on rock platform north of Mandorah, 18 July 1993, coll. K.R. Jensen.

Comparative remarks. This species has been recently described (Jensen 1993a), and only a few details will be added here. The specimens were all less than 2 mm long; one was newly metamorphosed, still partly swimming, partly crawling. It had no rhinophores, only thickened crests, as in *Limapontia capitata*; it had only one ceras on each side of the body. In body length it matched three cells of the *Rhizoclonium* sp., on which it was feeding. Two of the specimens were more darkly coloured than the others; the pigment was dark brown rather than the reddish brown noted in the original description.

In spite of the small size, the animals were reproductively active. The largest cerata contained a small branch of the albumen gland. Egg masses were sausage-shaped and contained 25-50 eggs.

Discussion. This species may be widespread in the Indo-West Pacific region. Specimens of similar external morphology have been collected from similar localities at Phuket, Thailand, and in Starfish Bay, Hong Kong (New Territories) (pers. obs.).

Family Plakobranchidae Rang, 1829

Plakobranchidae Rang, 1829.

Elysiidae Forbes and Hanley, 1856.

The inclusion of the genus *Plakobranchus* van Hasselt, 1824, in the Elysiidae (Jensen 1992) necessitates the changing of the family name to Plakobranchidae. Also, there is some confusion about the correct spelling. Apparently the original, Latin description of *Plakobranchus* in a Dutch journal was published two months prior to a more generally available "reprint" (with several modifications, see Bergh (1872), in a French journal, in which the spelling was *Placobranchus* (Burn, pers. comm.). I have not been able to confirm the actual publication dates of the two versions. The Plakobranchidae are the "parapodia-bearing" Sacoglossa. A family definition has been given in Jensen (1992). Phylogenetic relationships among the included genera remain unresolved (Jensen 1996).

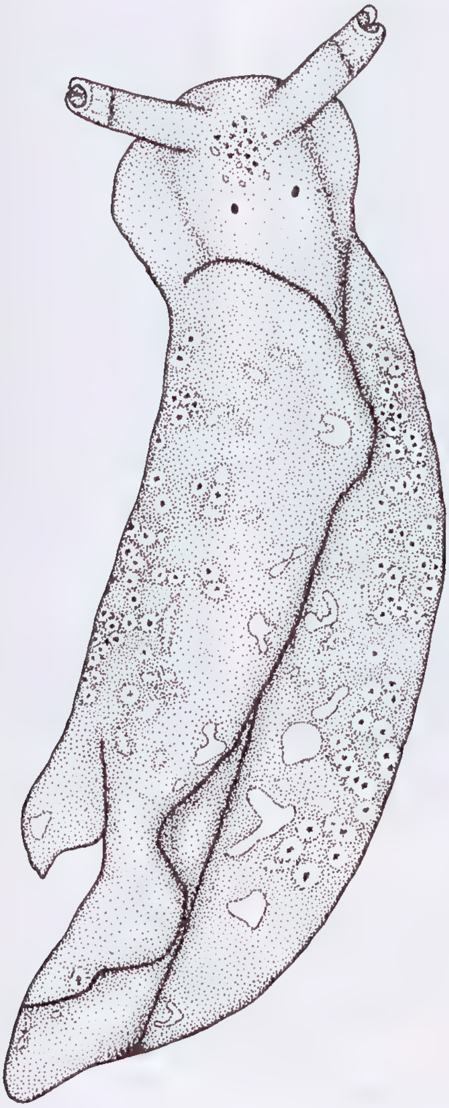

Fig. 14. *Elysiella stylifera* n. sp. Live animal drawn from colour slide by K.R. Jensen. Total length of animal ca. 20 mm.

Genus *Elysia* Risso, 1818

This genus contains upwards of 100 species. Externally they appear very similar, but anatomically there are large differences (e.g. Jensen 1992), and the genus will most likely have to be split as more species are studied anatomically. Synonyms have been listed in Jensen (1992).

Elysia australis (Quoy and Gaimard, 1832)

Material examined. 1 specimen, Lee Point, 6 July 1993, coll. K.R. Jensen; 1 specimen, Ludmilla Creek, coll. U. Sundberg, 12 July 1993.

Comparative remarks. The pigmentation of the small specimens was much lighter than in specimens from more southern localities in Australia, but the pattern of stripes on the head made identification almost certain, and examination of radular teeth confirmed the identification. Anatomical descriptions are given in Jensen and Wells (1990) and Jensen (1992). The smaller specimen (length about 2 mm alive) had a peculiar "malformation"; one eye was located in the pericardial region. However, the animal did not seem to be impaired by this.

The collection of *E. australis* in the Northern Territory extends the range of the species to be "circum-Australian".

Genus *Elysiella* Bergh, 1872

This genus has recently been redescribed, and a series of synonyms for the until now only known species, *E. pusilla* Bergh, 1872, have been listed (Jensen and Wells 1990; Jensen 1992). Although some variation in anatomy has been noted in specimens from different localities, features such as the unilaterally denticulate, triangular radular teeth and the very tall pharynx show little variation in specimens studied so far. The new species described here looked like a mutilated specimen of *E. pusilla*, and no particular effort was made in the field to describe colour, shape or behaviour, which may also differ from that of the typical species.

Elysiella pusilla Bergh, 1872

Material examined. 2 specimens (one partly dissected) from *Halimeda* sp., coll. by G. Edgar, off Charles Point, 12 July, 1993.

Comparative remarks. Anatomical descriptions have been published in Jensen and Wells (1990) and Jensen (1992). The present specimens were very small, and one was only partly dissected after discovering that what was thought to be the largest specimen was indeed another species. The specimens of *E. pusilla* did not have any black dots; nor did they have blue spots. Only a little brown pigment was found on the tips of the rhinophores. The smallest specimen (<2 mm preserved) had the typical unarmed penis.

As the two species of *Elysiella* apparently coexist in Darwin Harbour, a few specimens from other localities (Rottnest Island and Abrolhos Islands, Western Australia; Guam) were also partly dissected. These specimens all had an unarmed penis, thus they belonged to the typical *E. pusilla*.

Elysiella stylifera n. sp.

Type material. HOLOTYPE - NTM P6970, partly dissected (pharynx, nerve-ring and penis removed, and a SEM-stub with penis and radular teeth), from *Halimeda* sp. coll. by G. Edgar, off Charles Point, 12 July 1993.

Description. *Colour alive.* The general body colour is grass green. The animal has a submarginal row of irregularly shaped, opalescent light blue spots on the parapodia. White and black or dark brown dots are scattered on the external surface of the parapodia and on the head. The rhinophores have white tips and a brown submarginal band. White dots are dense middorsally on the head together with some opalescent blue spots. There is some brown pigment between the rhinophores. The inner surface of the parapodia and the dorsal surface of the central body are completely transparent. The foot sole is uniformly green. In the preserved specimen the tiny black dots remain, as well as a row of small, dark spots along the margin of the foot.

External features. The specimen resembles *Elysiella pusilla*, except that it has a very short tail (Fig. 14). However, it also has a partly torn parapodium, and it was considered a mutilated *E. pusilla* until dissected. The animal was about 20 mm long alive. The rhinophores (Fig. 15A) are rather long, rolled, and located close to the anterior border of the head; the rhinophore bases are close together. The foot sole is broad and distinctly set off from the dorsal part of the body, as in *E. pusilla*. The anteriormost pair of dorsal vessels enters the pericardium; this vessel is highly branched close to its entrance into the pericardium. The long renal ridge receives an additional seven pairs of branching vessels; there is a distinctly demarcated vessel on top of the renal ridge. The anus is on a papilla at the right anterior corner of the pericardium.

Internal anatomy. The pharynx is tall with a thick, long ascus-muscle ventrally (Fig. 15B). The posterior end of the descending limb of the radula is bent up on the left side of the pharynx, and this is where the densely packed, thin-walled ascus is located. The radular teeth (Fig. 16B-F) have triangular, narrow cusps with fine

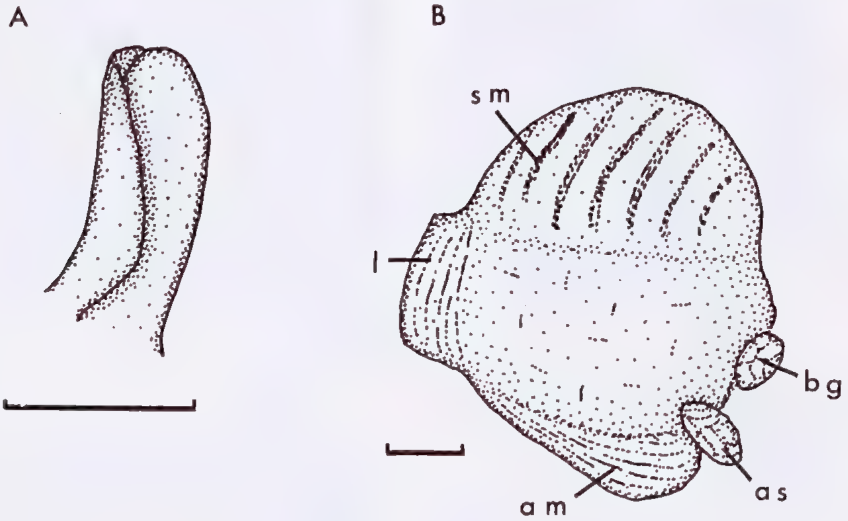

Fig. 15. Anatomy of *Elysiella stylifera* n. sp. A, rhinophore. B, pharynx. Scale bars: A = 0.5 mm; B = 0.1 mm. Abbreviations: **am**, ascus-muscle; **as**, ascus; **bg**, buccal ganglion; **l**, pharyngeal lips; **sm**, dorsal septate muscle.

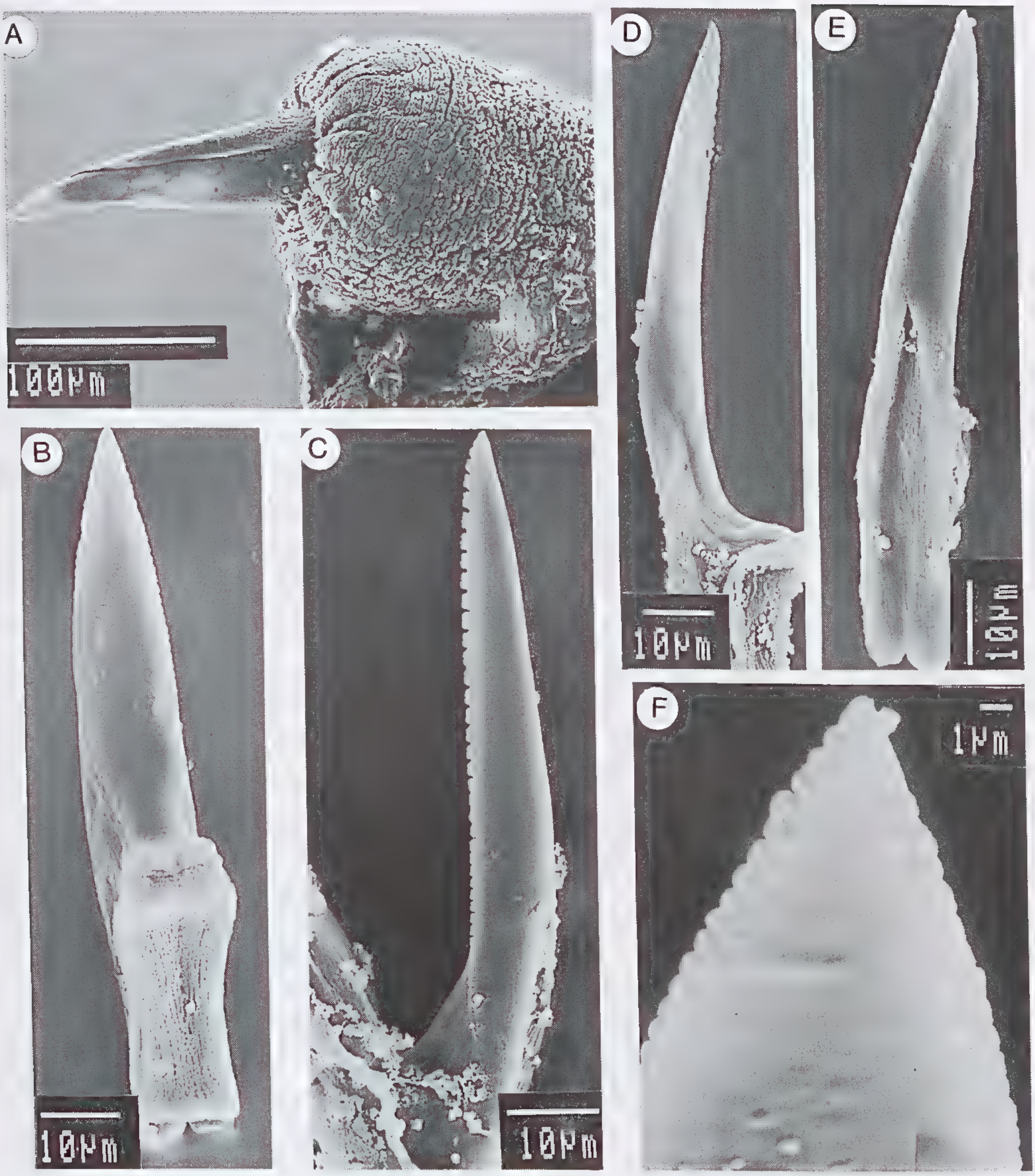

Fig. 16. Scanning electron micrographs of *Elysiella stylifera* n. sp. **A**, penis with stylet. **B**, radular tooth, frontal view. **C**, radular tooth, left lateral view. **D**, radular tooth, right lateral view. **E**, radular tooth, posterior view. **F**, detail of tip of radular tooth, frontal view.

denticles along both margins. The cusps appear to be very flat compared to those of *E. pusilla*. The radula contained 10 teeth in the ascending limb, 14 in the descending limb, and a densely packed heap of discarded teeth in the ascus. The teeth outside the ascus were about 85-90 µm long.

The most distinctive anatomical feature of this species is the conspicuous, straight penial stylet (Fig. 16A). In order to keep the only specimen as intact as possible, the remainder of the anatomy has not been studied.

Discussion. Marcus (1982) renamed the *Elysia halimedae (= Elysiella pusilla)* of Baba (1957) and Burn (1972) as *Elysia macnaei* because of its large parapodia and papillose rhinophores. The present specimen resembles this species in the size of the parapodia and short tail, but the rhinophores were not papillose in the present specimen. Other species which have been synonymized with *E. pusilla* are *Elysia dubia* Eliot, 1904, and *Elysia halimedae* Macnae, 1954 (Jensen and Wells 1990). However, a penial stylet has not been described from any of these, and hence the present specimen is evidently new to science. The radular teeth of *E. stylifera* are smaller than those of *E. pusilla* of comparable body size, and there are more teeth in the ascending as well as descending limbs of the radula. The shape of the pharynx is very similar. The presence of the penial stylet may help elucidate the phylogenetic position of the genus *Elysiella* in the family Plakobranchidae (= Elysiidae), because penial armature is rare, though probably plesiomorphic, in this family. However, the shape of the stylet is different from that of *Plakobranchus* as well as that of *Bosellia*. These two genera have a cylindrical stylet, whereas that of *E. stylifera* appears to be rolled. The peculiar radular teeth appear to be intermediate between those of *Thuridilla* and "normal" (blade-shaped) *Elysia* teeth; the cusp is triangular, but flat, and the cavity on the back side is deeper than that of *Thuridilla* teeth (and of *E. pusilla*), but shallower than that of most *Elysia*. Also, the two rows of denticles are not in the same plane, i.e. the cusps are slightly twisted.

Etymology. The specific name *stylifera* means "bearer of stylet" and refers to the penial armature of this species.

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A NEW FAMILY AND THREE NEW SPECIES OF FLATWORMS (PLATYHELMINTHES) FROM THE DARWIN HARBOUR AREA.

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ABSTRACT

Three new species of free-living flatworms are described from the Darwin Harbour area, northern Australia, *Torgea karlingi* gen. et sp. nov. (Torgeidae fam. nov., Prolecithophora) and *Pogaina hanleyi* n. sp. (Provorticidae) are marine species. *Gieysztoria billabongensis* n. sp. (Dalyelliidae) occurs in fresh water.

Keywords: Platyhelminthes, Rhabdocoela, Prolecithophora, Dalyelliidae, northern Australia, Provorticidae.

INTRODUCTION

Relatively few "microturbellarians" (i.e. free-living platyhelminths excluding Tricladida and Polycladida) are known from Australia. One species of the Acoela was described by Haswell (1905), who also reported a *Phaenocora* species (Typhloplanoida). Two *Mesostoma* and one *Plagiostomum* species collected in Western Australia were studied by Weiss (1910), Proseriata were studied by Ball and Hay (1977) and Martens and Curini-Galetti (1989). Two *Mesostoma* species from New South Wales were described by Kolasa and Schwarz (1988). Winsor (1988, 1990) described six species of Acoela from the Great Barrier Reef. The *Gyratrix hermaphroditus* species complex was studied in the Darwin area by Curini-Galletti and Puccinelli (1990). Faubel, Rohde and Watson (1994) described *Luriculus australensis* gen. et sp. nov. (Luridae) from the New South Wales coast, and Faubel, Blome and Cannon (1994) described four new species of Macrostomida from eulittoral marine habitats on the coast of southern Queensland and northern New South Wales. Two freshwater macrostomids were recorded by Sluys (1986), and Williams (1980) reported that the freshwater genera *Stenostomum*, *Catenula*, *Strongylostoma*, *Dalyellia*, *Bothromesostoma* and *Prorhynchus* had been previously recorded. *Bothrioplana semperi* was reported from a dam and billabongs near Darwin (Sluys and Ball, 1985). In an ecological study of shallow water marine sediments from Northern Queensland, Dittmann (1991) reported 107 unidentified free-living platyhelminth species, hence it is evident that only a small fraction of the fauna has been described to-date.

As a result of the work of Cannon (e.g. 1978, 1982, 1986, 1987 and 1993), symbiotic rhabdocoels, excluding the Neodermata, are better known than the free-living forms.

This paper reports on three free-living flatworm species collected in the Darwin Harbour area during the Sixth International Marine Biological Workshop. A new family within the Prolecithophora is recognized on the basis of one of these species.

SYSTEMATICS

Order Prolecithophora Karling, 1940
Family Torgeidae fam. nov.

Diagnosis. Prolecithophora with pharynx encased in a muscular sheath. Gonopore separate from mouth, in mid body. Gonads with tunica. Female gonads in the form of ovovitellaries with distinct ovarial and vitellarial parts.

In: Hanley, R.H., Caswell, G. Megirian, D. and Larson, H.K. (eds) *Proceedings of the Sixth International Marine Biological Workshop. The marine flora and fauna of Darwin Harbour, Northern Territory, Australia*. Museums and Art Galleries of the Northern Territory and the Australian Marine Sciences Association: Darwin, Australia, 1997: 187–197.

Etymology. The family is named in recognition of the outstanding contribution to platyhelminth research by Tor G. Karling during more than sixty years.

Torgea gen. nov.

Diagnosis. As for family.

Torgea karlingi n. sp.

(Figs 1-2)

Type material. HOLOTYPE - NTM WP 0100, one specimen anaesthetized in 7% $MgCl_2$, fixed in Bouins fluid, embedded and sectioned sagittally. Rock pool, lower shore, West Point, Darwin Harbour, 12 July 1993.

Additional material. One specimen, same locality, studied live.

Description. 2 mm long, dense, dark brown pigmentation rendering the live animal opaque. Paired pigmented eyes visible in live animals (Fig. 1).

Whole body surface ciliated. No ciliated furrow. Nuclei of the epidermal cells intraepithelial. Eosinophilous epitheliosomes present in the epidermal cells. Basal lamina thin and subepidermal musculature weak. Dark brown pigment subjacent to epidermis and surrounding internal organs. Brain encapsulated.

Pharynx anterior, conical and dorsoventrally oriented. Distally, pharynx free within pharyngeal pocket thus forming protrusible tube. Epithelium lining pharyngeal lumen ciliated. Buccal circular muscle fibres forming thick sheath surrounding pharynx. Prominent extrapharyngeal glands situated posterior to pharynx. Pharynx tube continuing posteriorly, forming muscular oesophagus. Intestine mediodorsal with pouch extending anterior to pharynx. Posterior part of intestine medially reaches caudal end of the animal and makes contact with the body wall. Gastrodermis unciliated. Conspicious eosinophilic glands (possibly part of a frontal gland complex) dorsally in the parenchyma (Figs 1-2).

Testes paired, one dorsal the other ventral, both joining common vesicle entering a short ejaculatory duct with muscular wall. Male copulatory organ an unarmed penis entering common genital atrium anterodorsally on papilla (Figs 1-2). Sectioned specimen at full male maturity, with large copulatory organ (that may have caused dorsal displacement of one of the testes). Separate ovarial and vitellarial parts of paired female gonads with ovaries anterior, one branch being ventral, other largely dorsal. Paired oviducts with eosinophilic glands joining common oviduct entering the common atrium posterior to penis papilla. Gonads are surrounded by tunica (Figs 1-2).

Remarks. Prolecithophorans with separate mouth and gonopore have been referred to either the Ulianinidae, Multipeniatidae, Plagiostomidae or Baicalarctiidae. These groups are conventionally brought together in the Separata. The remaining prolecithophoran taxa have a common mouth and gonopore and are by convention grouped in the Combinata. The Ulianinidae, Multipeniatidae and Plagiostomidae are set apart from *Torgea karlingi* by their posterior gonopore.

In the single species of the Baicalarctiidae, *Baicalarctia gulo,* Friedmann, 1926, found in Lake Baikal at 74-216 m depth, the gonopore is anterior, situated behind the pharynx. There are, however, a number of differences between *B. gulo* and *T. karlingi*. The former possesses a large anteriorly directed subterminal pharynx, the vitellaria are reticulate, live specimens of *B. gulo* are unpigmented and reach 40 mm length (Friedmann 1933). The pharynx of *T. karlingi* is conical and directed almost perpendicular to the length axis of the body. The vitellaria are compact, the worm is pigmented and 2 mm long.

The type of buccal musculature found in *Torgea karlingi* has hitherto not been found in any prolecithophoran. The substantial buccal muscle layer surrounding the pharynx in *T. karlingi* would facilitate extensive protrusion of the pharynx, and act as hydrostatic isolation relative to the parenchyma. The arrangement of the musculature forms an "external pharynx" somewhat similar to the anteroterminal pharynx coniformis in *Gnosonesima* (Lecithoepitheliata) (Karling 1968). The structure of the latter is more complex, however, with the external muscle layer forming a protrusible proboscis around the pharynx. Other features of the anatomy differ widely between the two taxa.

The status of the Prolecithophora as a monophylum within the Platyhelminthes was demonstrated by Ehlers (1988), but the monophyly of extant families of the Prolecithophora is unclear in some cases. The largest prolecithophoran group, the Plagiostomidae, is morphologically rather homogeneous, but shows no apparent synapomorphies, i.e. there is no evidence for its

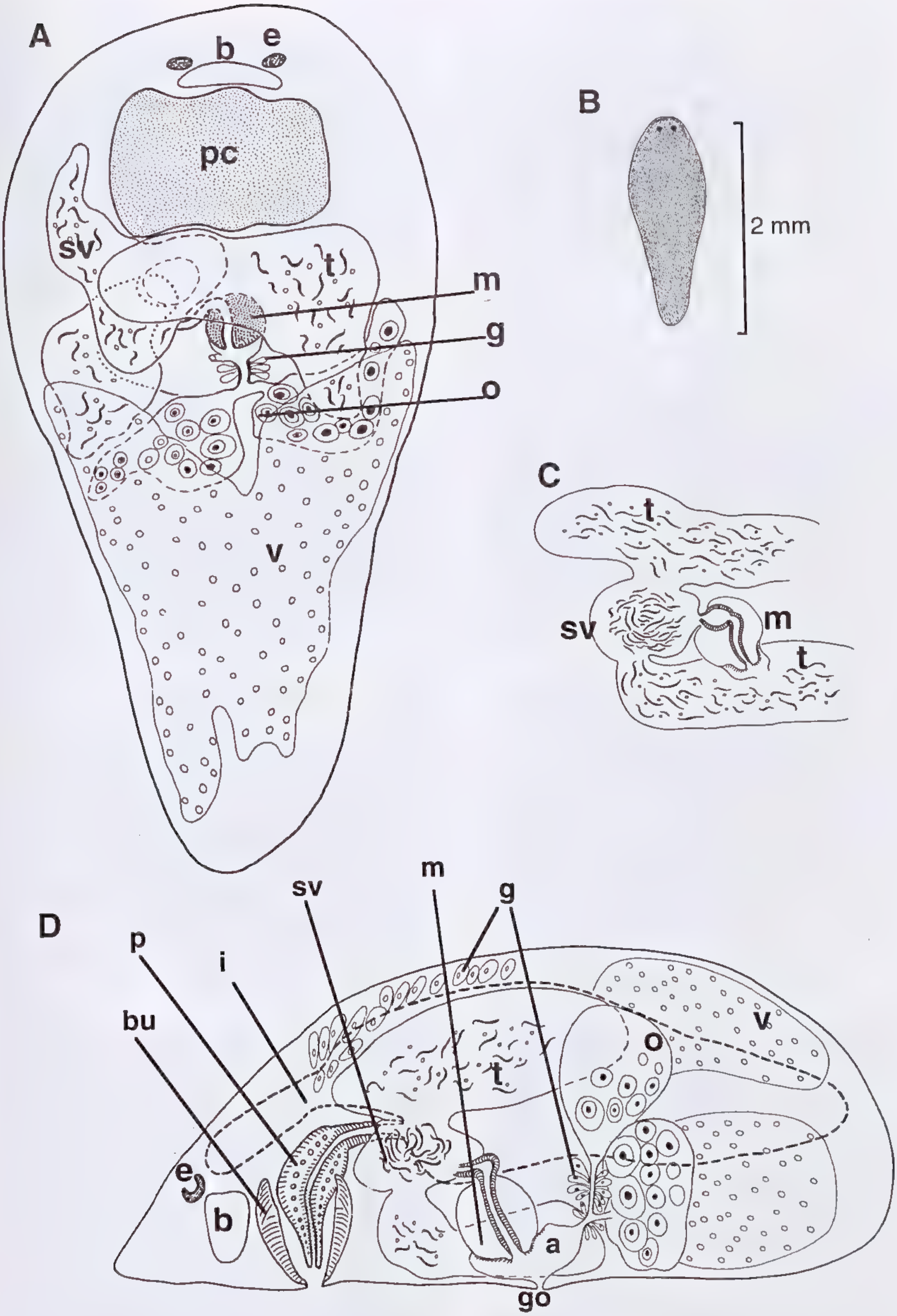

Fig. 1. *Torgea karlingi*. fam. et gen. et sp. nov. **A**, dorsal view reconstructed from serial sections; **B**, habitus ; **C**, diagram of male organs; **D**, Sagittal view reconstructed from serial sections. Abbreviations used: **a**, common atrium; **b**, brain; bu buccal musculature; **c**, copulatory bursa; **e**, eye; **g**, eosinophilic glands; **go**, gonopore, **i**, intestine; **m**, male copulatory organ; **o**, ovary (ovarial part of ovovitellarium); **p**, pharynx; **pc**, pharyngeomuscular complex; **v**, vitellarium (vitellarial part of ovovitellarium); **sr**, seminal receptacle; **sv**, seminal vesicle.

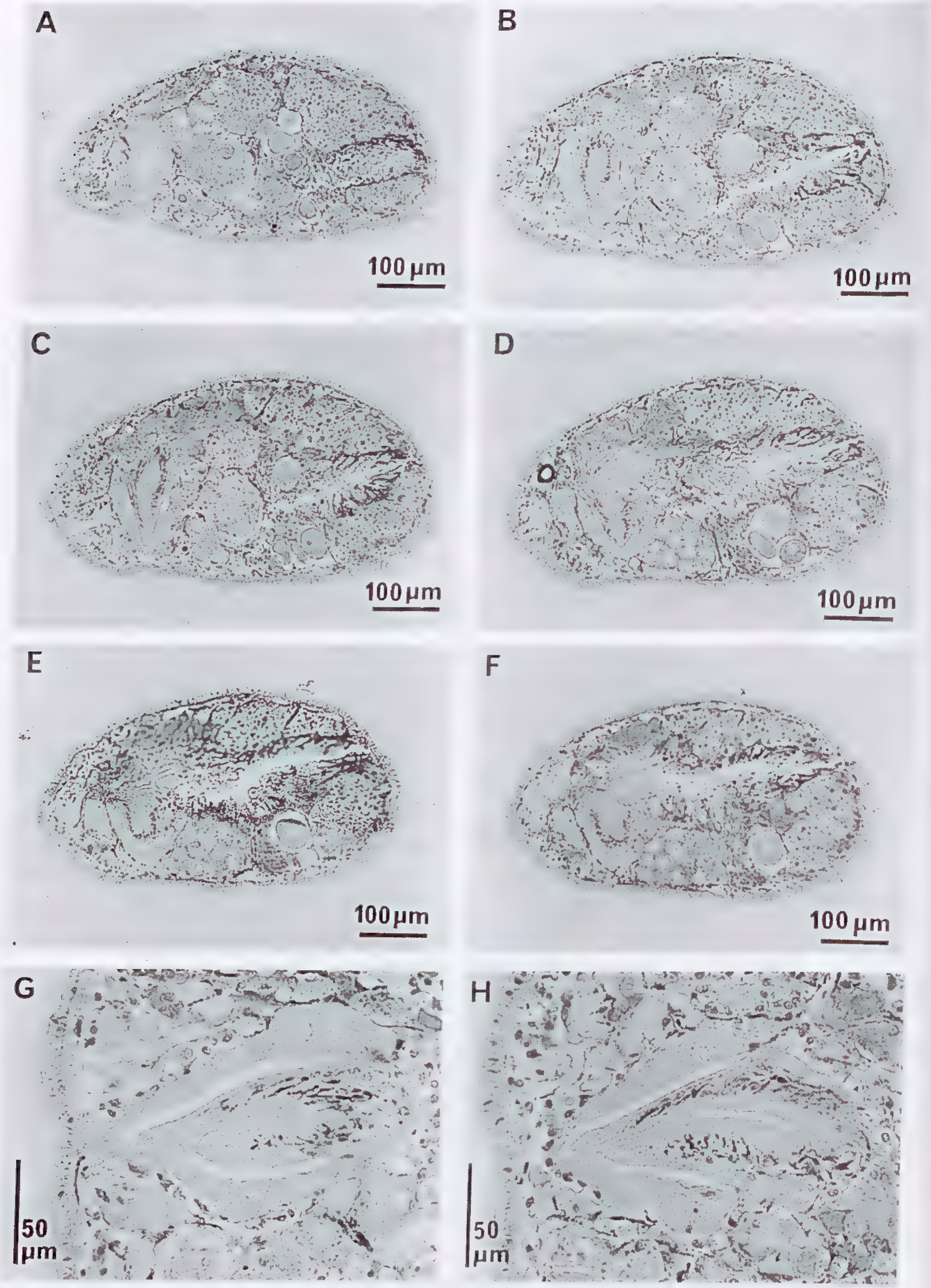

Fig. 2. *Torgea karlingi* fam. et gen. et sp. nov. Light micrographs of a series of sagittal sections. Note buccal musculature surrounding pharynx. Intestine close to posterior body wall in **D**. **G** and **H** show a higher magnification of pharynx and buccal musculature.

monophyly. The groups Cylindrostomidae and Pseudostomidae are together characterized by possession of two pairs of eyes (three in *Reisingeria hexaoculata* Westblad, 1955, none in *Gonostomula anocelis* Westblad, 1955, *Allostoma amoneum* Karling, 1962, and *Euxinia baltica* Meixner, 1938; the existence of closely related species with eyes indicates that the absence of eyes is secondary in the latter two species). Furthermore, Karling (1940, 1993) reports concentration of the ventral longitudinal body wall musculature as a feature of the Cylindrostomidae and Pseudostomidae. The individual monophyly of the two groups, on the other hand, is unsubstantiated.

The taxon Multipeniatidae (referred to the Plagiostomidae by Meixner (1938) and Karling (1961)) can be identified as a monophylum through the presence of multiple male copulatory organs. The monotypic Baicalarctiidae have reticulate vitellaria and a separate anterior gonopore. The Ulianinidae have cleptocnids in the parenchyma and possess a large medioventral pharynx oriented perpendicular to the body length axis. The Scleraulophoridae are distinguished by a long, tubular oesophagus somewhat similar to the oesophagus in *Torgea karlingi*. The distinction between the two pharyngeal types (pharynx plicatus and ph. variabilis) that occur within the Prolecithophora is problematic and perhaps arbitrary, since the septum separating pharynx and parenchyma in the latter may be more or less feebly developed (Karling 1962). Furthermore the pharynx plicatus may be derived independently in several groups (Ehlers 1985). Hence occurrence of either of the two pharyngeal types cannot at present be used to evaluate phylogeny. The scattered distribution of pharynx plicatus and pharynx variabilis within the Prolecithophora corroborates this view.

The groups Genostomatidae and Urastomidae have traditionally been referred to the Prolecithophora based on similarities in the reproductive organs, e.g. the occurrence of a common oral-genital pore, but recent ultrastructural studies support the view that they are most likely Rhabdocoela (Hyra 1993, with references).

While apparently a member of the Prolecithophora, *T. karlingi* cannot be referred to any previously described family within the group. Thus the family Torgeidae is recognized. There is no comprehensive study of the phylogeny of the Prolecithophora — i.e. sister group relationships are unknown. Hence *Torgea karlingi* is classified on the basis of previous conventional diagnoses of taxa.

Order Dalyellioida Meixner, 1924
Family Provorticidae Beklemischev, 1927

Pogaina hanleyi n.sp
(Figs 3-4)

Type material. HOLOTYPE - NTM WP 0101, sand pool, mid shore, Lee Point, Darwin Harbour, one sagittally sectioned specimen, 8 July 1993. PARATYPES- SMNH 4902, same locality as holotype and sand pool, mid shore West Point, Darwin Harbour, two wholemounts, two sagittally sectioned specimens and two cross sectioned specimens, 22 July 1993.

Description. Rounded, cylindrical, 0.5-0.6 mm long. Body form variable, sometimes more elongate. Body with yellowish zooxanthellae in parenchyma. Dark pigment spots in anterior, posterior end with continuous dark pigmentation (Figs 3-4). Conspicuous eyes with highly refractile lensing structures in the anterior. Pharynx oviform, in anterior body. Intestine sac-like.

Common gonopore in posterior part of body. Muscular atrium proximal to gonopore. Paired testes lateral in mid body. Seminal vesicle opens into copulatory bulb with distally positioned prostatic tissue (Fig 4). Copulatory stylet a 110-130 µm long tube distally club-like with two terminal claws (Figs 3-4).

Paired vitellaria dorsolateral in posterior half of body. Discrete, paired ovaries situated ventral to vitellaria close to gonopore. Seminal receptacle containing spermatozoa extending posteriorly from the female duct (Figs 3-4).

Remarks. The morphology of the sclerotized parts of the male copulatory organ is variable within the genus *Pogaina*: a short, broad and cup-like organ is present in *P. kinnei* Ax, 1970, *P. bicornis* Karling, 1986 and *P. evelinae* (Marcus, 1954); in *P. adriatica* (Dörler, 1900), *P. alaskana*, Ax and Armonies, 1990, *P. arcassonensis* Ehlers and Sopott-Ehlers 1989, *P. murmanica* (Graff, 1905), *P. paranygulgus* Karling, 1986, *P. ussurensis* (Nassonov, 1932) *P. suslica* Marcus, 1951 and *P. oncostylis* Ax and Armonies, 1987, the male organ is a funnel shaped tube (in the latter two species with an accessory hook). *Pogaina suecica* (Luther, 1948), *P. tifa* Marcus, 1954 and *P. hanleyi* have a long, distally curved tube with terminal claws.

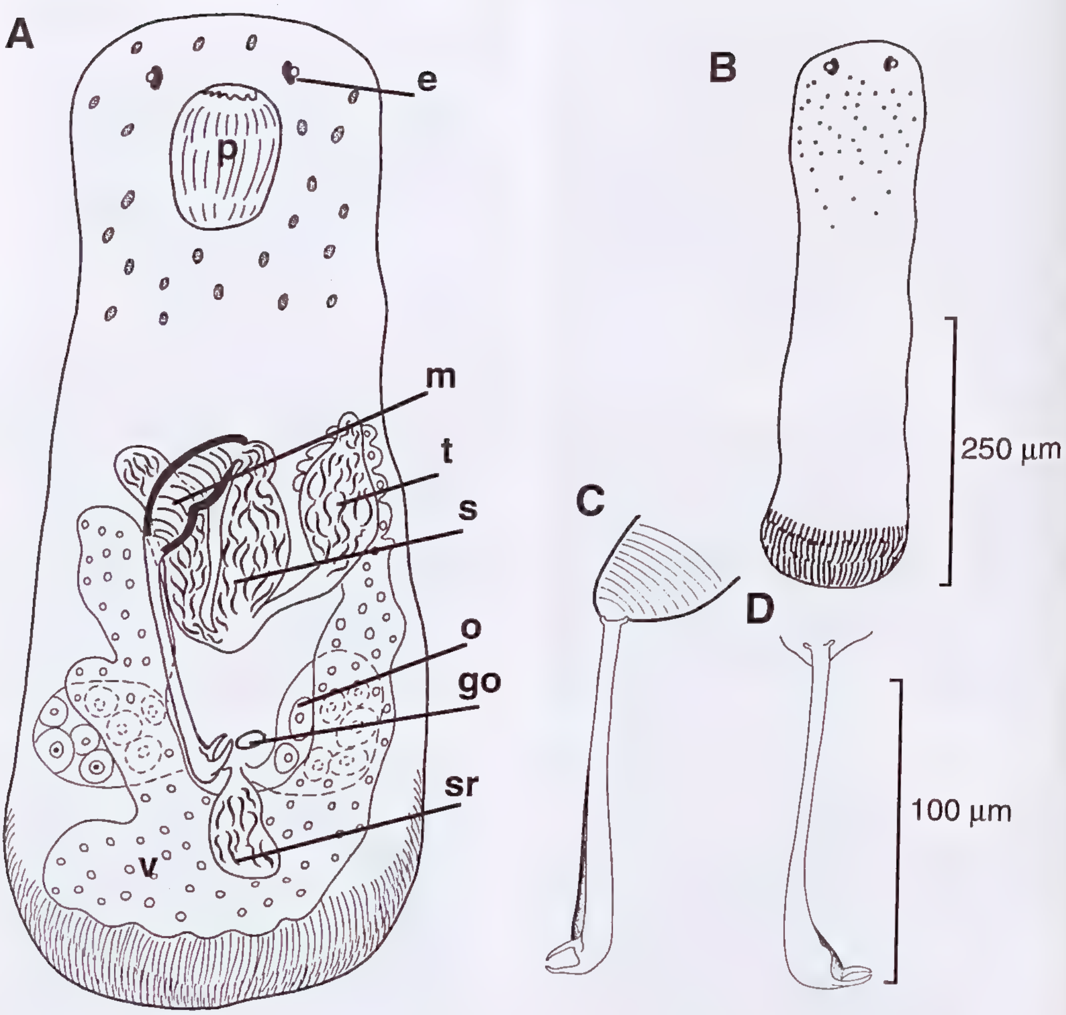

Fig. 3. *Pogaina hanleyi* n. sp. **A**, dorsal view reconstructed from live specimens and serial sections. **B**, habitus. **C** and **D**, copulatory stylets from two specimens. Abbreviations used: **a**, common atrium; **b**, brain; **bu** buccal musculature; **c**, copulatory bursa; **e**, eye; **g**, eosinophilic glands; **go**, gonopore, **i**, intestine; **m**, male copulatory organ; **o**, ovary (ovarial part of ovovitellarium); **p**, pharynx; **pc**, pharyngeomuscular complex; **v**, vitellarium (vitellarial part of ovovitellarium); **sr**, seminal receptacle; **sv**, seminal vesicle.

In *P. suecica* and *P. tifa,* the tube possesses a flange, and testes and vitellaria extend anteriorly to the level of the pharynx. The male organ of *P. hanleyi* is club-shaped distally, the distal claws are more prominent than in the two former species and testes and vitellaria have a more posterior position. *Pogaina tifa* is 0.2-0.3 mm long, thus a smaller species; *P. suecica* is 0.6-1.0 mm long, thus larger than *P. hanleyi.*

The systematics of the Provorticidae is in need of revision. Genera have been introduced without evidence of monophyly. In fact, the monophyly of the family Provorticidae itself is unsubstantiated by apomorphies. Until a cladistic revision of the group has been carried out, new taxa therefore have to be provisionally placed in genera based on conventional diagnoses, i.e. morphological similarity. The genus *Pogaina* was erected by Marcus (1954) to accommodate Provorticidae of the subfamily Kirgisellinae with paired separate testes, paired vitellaria and a stylet. All of these features are likely to be plesiomorphies within the Provorticidae. However, two apomorphies can be proposed for species within the genus *Pogaina:* zooxanthellae in the parenchyma and dark pigmentation in

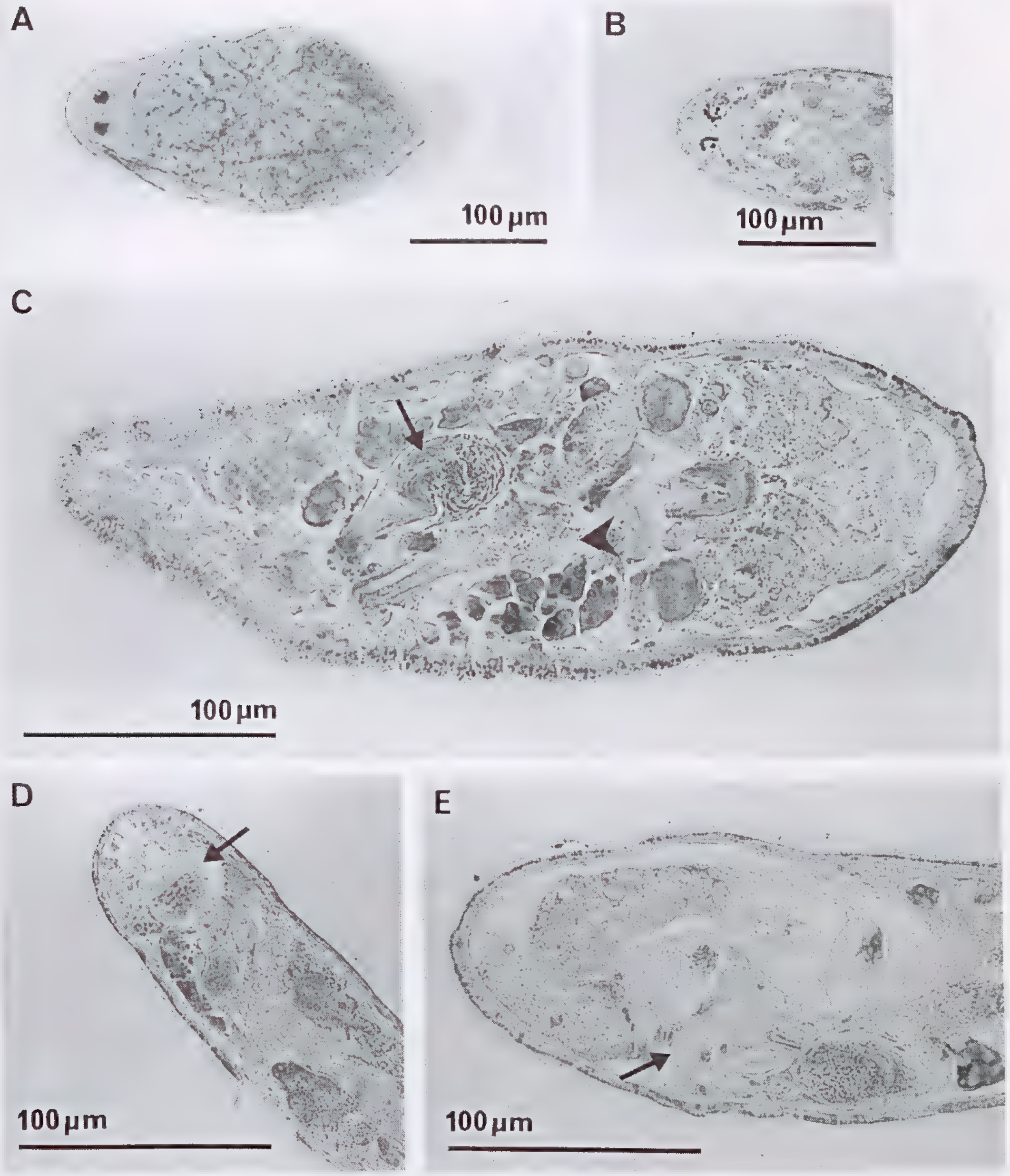

Fig. 4. *Pogaina hanleyi* n. sp. Light micrographs. **A**, whole mount. **B**, horizontal section showing pigment cups of eyes and brain. **C**, para-horizontal section (anterior to the left) showing seminal vesicle (arrow) and protstatic tissue (arrowhead). **D**, horizontal section of anterior part showing pharynx (arrow). **E**, sagittal section of posterior part (anterior to the right), showing muscular atrium (arrow) and associated structures.

spots or larger patches. Refractile lenses in the eyes occur in *Pogaina*, but also in some other taxa of the Rhabdocoela, see Sopott-Ehlers (1993) for references. Hence the lenses could be interpreted either as a synapomorphy for a large sub-taxon of the Rhabdocoela, or if independently evolved, as apomorphies of several smaller taxa, one of them *Pogaina*. Further studies of rhabdocoel photoreceptor ultrastructure are needed before a choice can be made between the two hypotheses.

Etymology. The species is named after Dr Russell Hanley, organizer of the Darwin workshop.

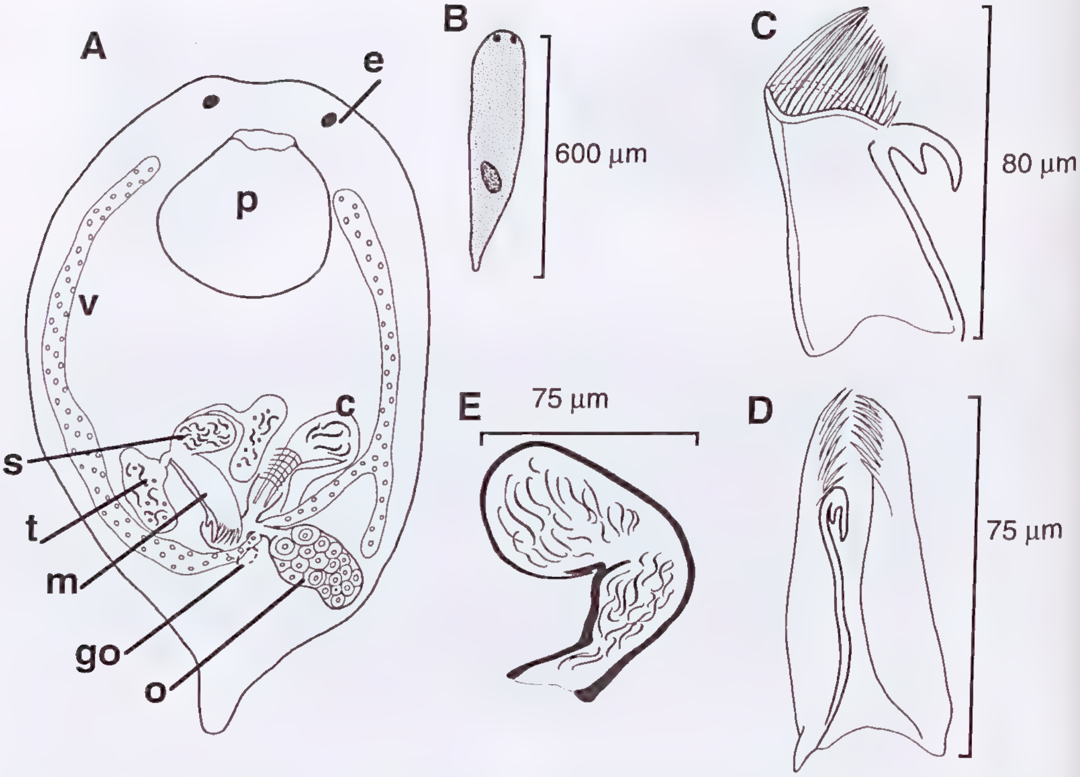

Fig. 5. *Gieysztoria billabongensis* n. sp. **A**, dorsal view, reconstructed from live specimens, whole mounts and serial sections; **B**, habitus; **C** and **D**, male stylets from two different specimens, combined from live worms and wholemounts; **E**, copulatory bursa drawn from wholemount Abbreviations: **a**, common atrium; **b**, brain; bu buccal musculature; **c**, copulatory bursa; **e**, eye; **g**, eosinophilic glands; **go**, gonopore, **i**, intestine; **m**, male copulatory organ; **o**, ovary (ovarial part of ovovitellarium); **p**, pharynx; **pc**, pharyngeomuscular complex; **v**, vitellarium (vitellarial part of ovovitellarium); **sr**, seminal receptacle; **sv**, seminal vesicle.

Order Dalyellioida Meixner, 1924
Family Dalyelliidae Graff, 1908

Gieysztoria billabongensis n.sp
(Figs 5-6)

Type material. HOLOTYPE - NTM WP 0102, billabong connected to freshwater stream discharging into Stephen's Creek, West Arm, Darwin Harbour. Underside of water lily leaves (*Nymphaea* sp.) one specimen, wholemount, 15 July 1993. PARATYPES - SMNH 4901, two sectioned specimens, one horizontally, one sagitally. Three wholemounts. Same locality as holotype.

Description. 0.5-0.6 mm long, rounded, with blunt anterior, posteriorly tapering. Green colouration from symbiotic zoochlorellae in parenchyma in all studied specimens, brown egg capsule in uterus visible in some specimens. Two pigmented eyes near anterior end. Large pharynx doliiformis, about 25 % of body length, anteriorly directed. Mouth anterior, subterminal (Figs 5- 6).

Male copulatory organ about two thirds of body length from anterior end. Trough-like cingulum (Gürtel) of cuticular apparatus about 50 µm long and has no fenestrae. Proximally, cingulum concave. Numerous (more than 20) distally curved spines symmetrically arranged, their length increasing towards bottom of cingulum. Longest spines about 30 µm. One bifid, hook-shaped edge-spine, wider than others, present on one side of cingulum. Proximal to penis, a seminal vesicle of about same height as cingulum. Seminal vesicle surrounded by prostatic tissue. Two testes situated on either side of male copulatory organ (Figs 5-6).

Single ovary situated at about same level as male copulatory apparatus, but somewhat to right of body midline. The prominent copula-

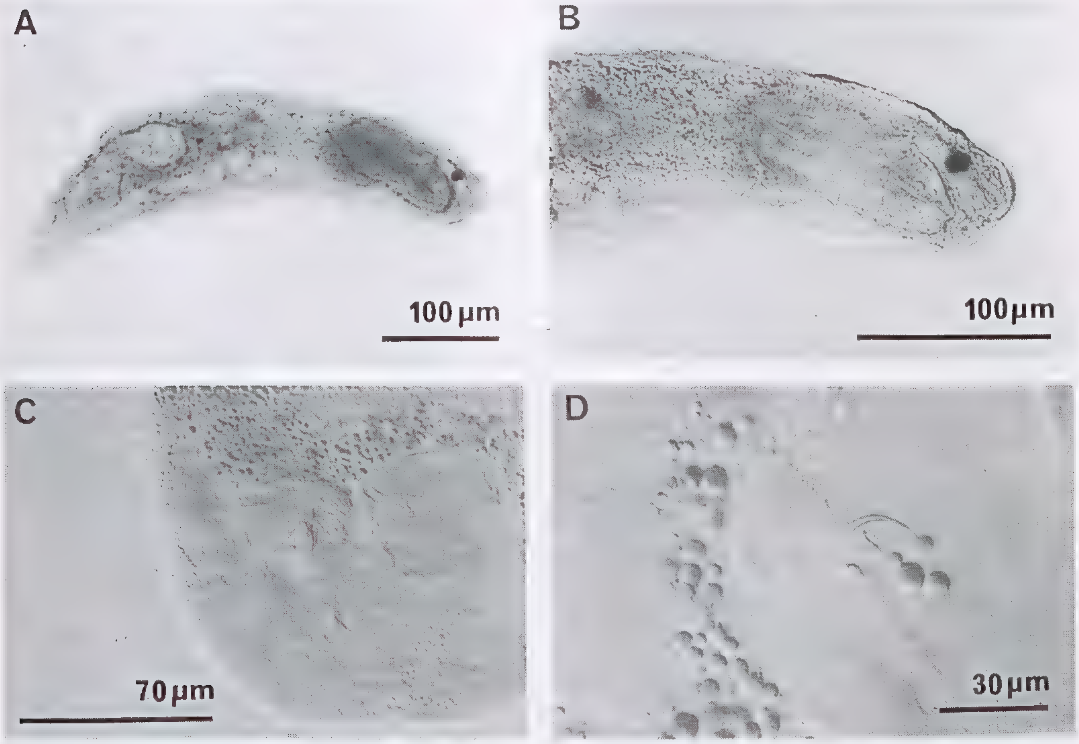

Fig. 6. *Gieysztoria billabongensis* n. sp. Light micrographs of whole mounts. **A**, specimen with egg capsule posteriorly. **B**, anterior part of worm with prominent doliiform pharynx. **C**, posterior part of squeezed specimen showing uterus and male copulatory organ. **D**, male copulatory organ from another squeezed specimen.

tory bursa is composed of two parts: distally a long muscular stalk, about 70 µm long, and proximally bursal bulb about 75 µm wide. In mature specimens the uterus contains one brown egg capsule. Vitellaria lateral, smooth (i.e. not papillose) and reaching anteriorly to level of pharynx (Figs 5-6).

Etymology. The name refers to the habitat (type locality).

Remarks. The complex male armature and the single ovary are likely apomorphies of the Dalyelliidae, which is a very speciose group with *Microdalyellia* and *Gieysztoria* the largest genera. Monophyly of genera within the Dalyelliidae is less well substantiated, but *Gieysztoria* and *Microdalyellia* have male sclerotized organs with distinctive morphologies. In his comprehensive monograph of the Dalyelliidae, Luther (1955) lists 59 species within *Gieysztoria* and 34 species within *Microdalyellia*. Since then new species have been described by van der Land (1965). Young (1977) and Kolasa (1978, 1981). As with a number of other freshwater inhabiting flatworms, many of the *Gieysztoria* species have a very wide distribution, e.g. the large species (1-1.6 mm) *G. rubra* Fuhrmann, 1894, which has been recorded in Europe, Africa and South America (Rixen 1961, Young 1977). Identification of species in the genus is dependent on the sclerotized male structures. The male copulatory organ in *G. billabongensis* resembles the one found in *G. pavimentata* Beklemishev, 1926, but differs in the shape of the edge spine. *G. pavimentata* is longer than *G. billabongensis*: 0.8-1.0 mm µm as opposed to 0.5-0.6 mm, and rarely has zoochlorellae (Luther 1955). Other species that resemble *G. billabongensis* in the structure of the male copulatory apparatus are *G. italica* Luther, 1955 and *G. uncia* Marcus, 1946. However, the cingulum in the two latter species is much shorter than in *G. billabongensis* and neither of them possesses the distinctive edge-spine. The concave outline of the proximal cingulum is a character intermediate between *Microdalyellia* and *Gieysztoria*. However, the armature and general structure of the copulatory organ is of the "*Gieysztoria* type" (Luther 1955). The posterior position of the testes is another feature interpretable as an apomorphy for the taxon *Gieysztoria*.

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OBSERVATIONS ON SOME INTERTIDAL MARINE PROSOBRANCH MOLLUSCS FROM DARWIN HARBOUR, NORTHERN TERRITORY.

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ABSTRACT

The following six common littoral prosobranch gastropods from the Darwin region (Northern Territory, Australia) have been studied: *Nerita histrio* Gmelin, 1791, *Nerita reticulata* Karsten, 1789, *Pugilina cochlidium* (Linnaeus, 1758), *Nassarius* (*Zeuxis*) *dorsatus* (Röding, 1798), *Nassarius (Zeuxis) fraudator* Cernohorsky, 1980, and *Cronia margariticola* (Broderip, 1833). The egg capsules of all six species are described and figured; but the assignment of the egg capsule of *Cronia margariticola* is doubtful. The egg capsules of *Nerita historio*, *Pugilina cochlidium*, *Nassarius (Zeuxis) fraudator* and *Cronia margariticola* are hitherto undescribed. Detailed descriptions are given for the two species of *Nerita*, where the microsculpture of the opercula and the egg capsules have been studied. The possibility of using these characters in the taxonomy in the genus *Nerita* is discussed. The geographical distribution in the Indo-West Pacific region of the species mentioned has been outlined and notes on habitat are given.

KEYWORDS: Littoral, marine prosobranchs, egg capsules, Northern Territory, Australia.

INTRODUCTION

Between 5 and 23 July 1993 I had the opportunity to study marine prosobranchs around Darwin Harbour, Northern Territory, Australia. My interest focused on aspects of reproductive strategy, zoogeography and taxonomy of some common intertidal prosobranchs. The egg capsules of six species were obtained and described: *Nerita histrio* Gmelin, 1791, *Nerita reticulata* Karsten, 1789, *Pugilina cochlidium* (Linnaeus, 1758), *Nassarius (Zeuxis) dorsatus* (Röding, 1798), *Nassarius (Zeuxis) fraudator* Cernohorsky, 1980, and ?*Cronia margariticola* (Broderip, 1833). The sculpture of the opercula of the two species of *Nerita* is described.

The samples were fixed in 10% formalin before transfer to 80% ethanol, which was changed after one or two days. The material from the study is kept at the Zoological Museum of the University of Copenhagen (hereafter: ZMUC).

The study of the egg capsules of marine prosobranchs is a base for the study of their reproductive strategy and in many cases provides systematic characters. Reference is made to the discussion in D'Asaro (1991, 1993).

SYSTEMATICS

Neritidae Rafinesque

Mienis (1978) figured the external face of the opercula of three species of *Nerita*: *N. adenensis* Mienis, *N. polita* Linnaeus and *N. patula* Récluz. That of the first is completely smooth, and the inner face is wrinkled near the apophysis. In *N. polita* the outer edge is distinctly sculptured, whereas the remaining 3/4 of the outer face has fine striae radiating from the nucleus. In *N. patula* the outer face is completely covered by minute pustules.

Hill (1980) gave brief descriptions and (somewhat obscure) figures of 12 species of *Nerita* from Hong Kong waters. He concluded that in most species the shape and sculpture of the

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opercula are distinctive specific characters. The present study of two species supports this view.

The egg capsules of the individual taxa of the Neritidae are very similar: lens-shaped, oval or circular, consisting of a membranous base and a solid domed top. In all species studied the top is reinforced by inclusions. Andrews (1935) stated that in *Nerita* the reinforcement bodies were globular spherulites produced by the digestive gland and concluded that the size, form and arrangement seem to be a specific character. Andrews states that in the freshwater genera *Neritina* and *Theodoxus*, the reinforcement bodies originate from the surrounding sediment, consisting of sand grains and shells of diatoms and foraminiferans. Examples of the two types of reinforcement bodies are given.

Knudsen (1992) gave a brief account of the phenomenon in some of the earlier literature. He gave micrographs of three species of Neritidae from Hong Kong waters: *Clithon oualaniensis* (Lesson), *Nerita albicilla* Linneaus, and *N. chamaeleon* Linnaeus. In *N. albicilla* the reinforcement bodies are regular globose spherulites measuring 45-60 µm, whereas the two other species apparently use sediment particles.

Nerita histrio Gmelin, 1791
(Figs 1-3)

Nerita histrio Gmelin, 1791: 3681.
Nerita squamulata Le Guillou, 1841: 344.
Nerita (Theliostyla) squamulata - Cernohorsky 1972: 50, pl. 11, fig. 4. - Wells and Bryce 1988: 49, fig. 110; - Wilson 1993: 41, pl. 2, fig. 3a-c.

Material. Fannie Bay, Darwin, 6 July 1993, 6 specimens and 4 egg capsules (ZMUC).

Introductory remarks. Adam and Leloup (1938) synonymized *Nerita squamulata* Le Guillou, 1841, with *Nerita chamaeleon* Linnaeus, 1758, without comments. They state that the species is easily recognized by its large spiral bands, which are alternating black and orange. Cotton (1959) lists *Theliostyla chamaeleon*, but not *N. squamulata*. Cernohorsky (1972) considered *Nerita (Theliostyla) squamulata* a separate species and pointed out several distinguishing characters. Wium-Andersen (1977), studying marine Neritidae from Phuket (the west coast of Thailand), kept *Nerita chamaeleon* and *N. squamulata* as separate species. She added the following remarks: "Some authors consider *N. squamulata* an ecological form of *N. chamaeleon*. At Phuket the two taxa can be distinguished although intermediates can be found", and concluded that only closer examination can show if they should be considered two subspecies of the same species. The material studied by Wium-Andersen is kept at the ZMUC and was inspected during the present study. H.K. Mienis (pers. comm.) states that the specific name *squamulata* should be replaced by *histrio*.

Considering the problem just outlined, a description and figures are justified.

Description. *Shell* (Figs 1A, 2A). The spiral ribs are irregular, rounded and separated by narrow grooves. A fine transverse sculpture crosses the ribs in an oblique direction. The columellar edge is curved and has three to four small rounded teeth. The parietal region is concave and has irregular sharp folds. The interior

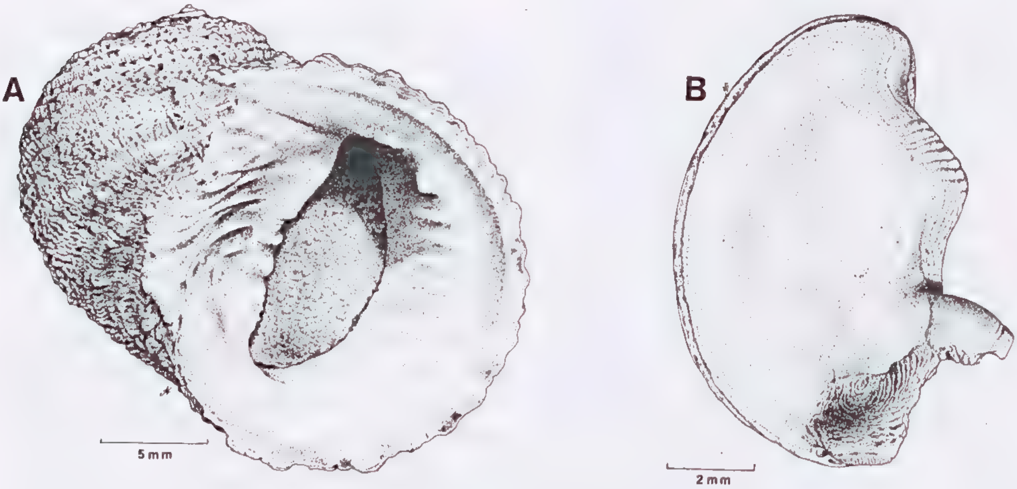

Fig. 1. *Nerita histrio.* **A**, apertural view, **B**, internal face of the operculum.

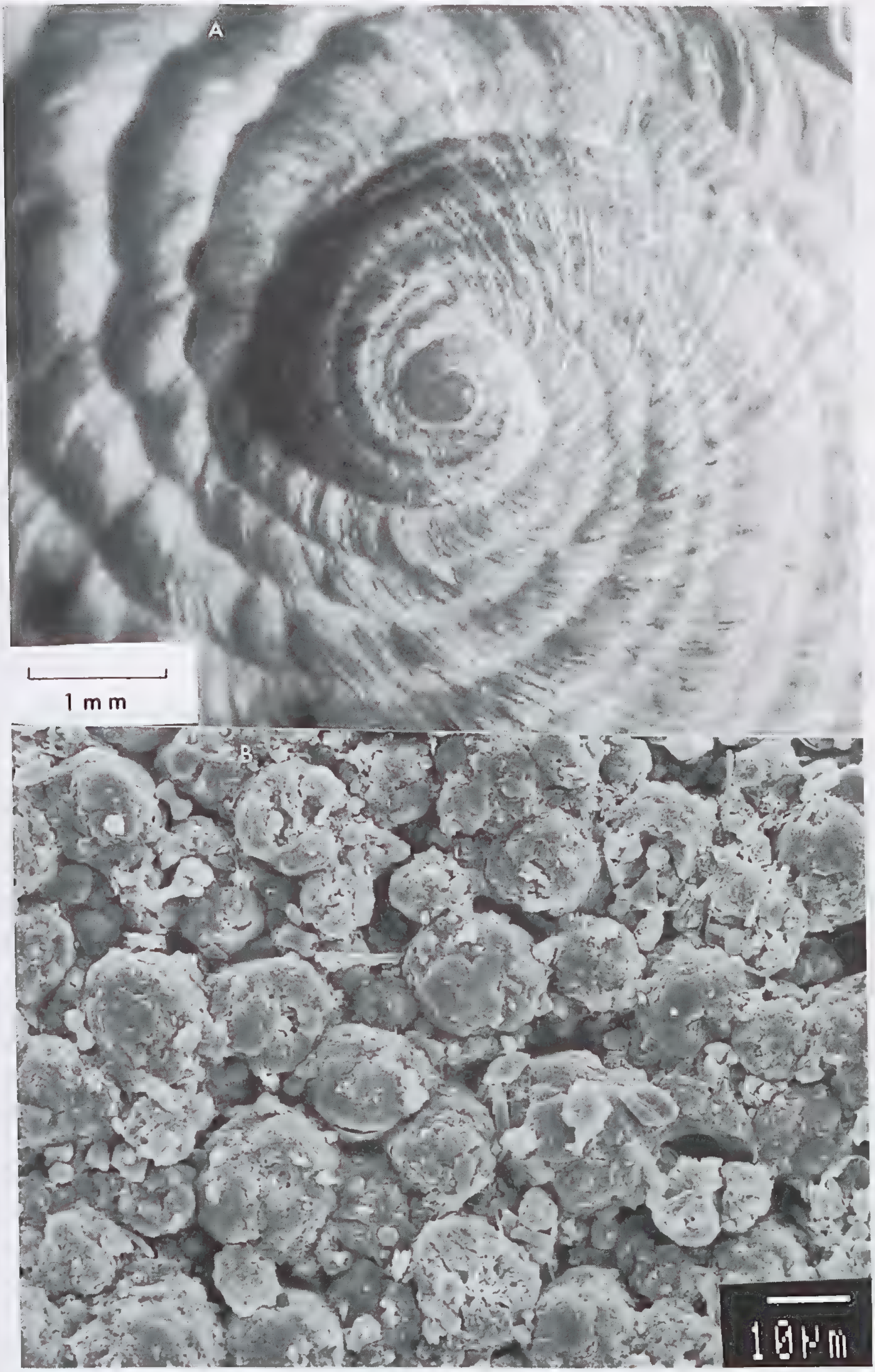

Fig. 2. *Nerita histrio*. **A**, detail of the protoconch and upper whorls of the teleoconch. **B**, reinforcement bodies of an egg capsule.

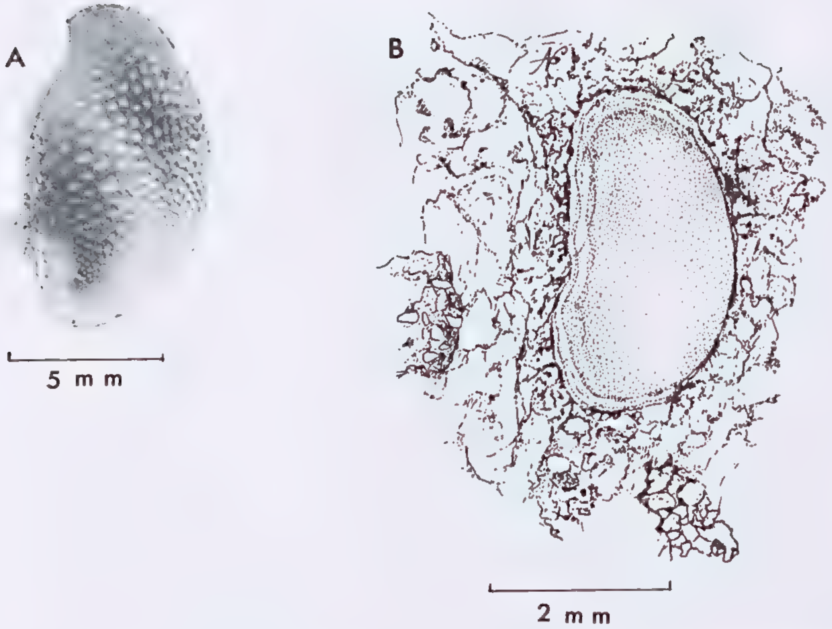

Fig. 3. *Nerita histrio*. **A**, external face of the operculum. **B**, egg capsule.

of the outer lip has about seven to eight rather indistinct denticles. The colour is yellowish. The largest shell has a length of 22 mm.

Egg capsule (Figs 2B, 3B). The egg capsule is bean-shaped, measuring 2 x 1.3 mm. The capsule wall has two types of irregularly distributed reinforcement bodies: irregularly rounded bodies with diameters of about 15 µm, interspaced with smaller ones of 1-4 µm, some of which appear to be shell fragments. The larger bodies give the impression of being conglomerate composed of smaller bodies.

Habitat. Stray specimens were found, often on the lower part of boulders consisting of calcareous matter (? beach rock). The animals were often sitting in pairs. A pair of individuals were located close to the egg capsules collected. No other species of *Nerita* were present at the site.

Distribution. The taxon is widely distributed in the Indo-West Pacific region. Thus it has been recorded from Sri Lanka and the west coast of Thailand and southern Japan. In the Pacific it does not extend to Hawaii or Fanning Island. In Australia it has been recorded from North West Cape (about 22°S) to northern Queensland.

Nerita reticulata Karsten, 1789

(Figs. 4-6)

Nerita reticulata Karsten, 1789: 296; - Risbec 1932: 363, figs 1-11; - Wells 1978: 281, fig. 8; - 1980: 240.

Nerita (Theliostyla) reticulata Adam and Leloup 1938: 52, pl. 4, fig. 5.

Theliostyla reticulata Cotton 1959: 273.

Nerita (Ritena) reticulata Cernohorsky 1972: 52, pl. 11, fig. 10.

Material. Southeast of Darwin, on sandflat near mangrove, 8 July 1993, 17 specimens (ZMUC). The specimens were kept alive in a glass jar (about 1 liter) with a few pieces of sandstone from the collecting site. On 14 July, four or five egg capsules were deposited on the sandstone.

Description. *Shell* (Figs 4A, 6A). The largest specimen had a shell length of 11 mm (20 mm recorded by Cernohorsky 1972). The shell has rounded, somewhat irregular spiral ribs, often with broad interstices. The latter may have one or two finer spiral ribs. About 15 primary ribs are present on the body whorl. A faint, close-set, transverse sculpture is formed by the rather solid periostracum. The columella has

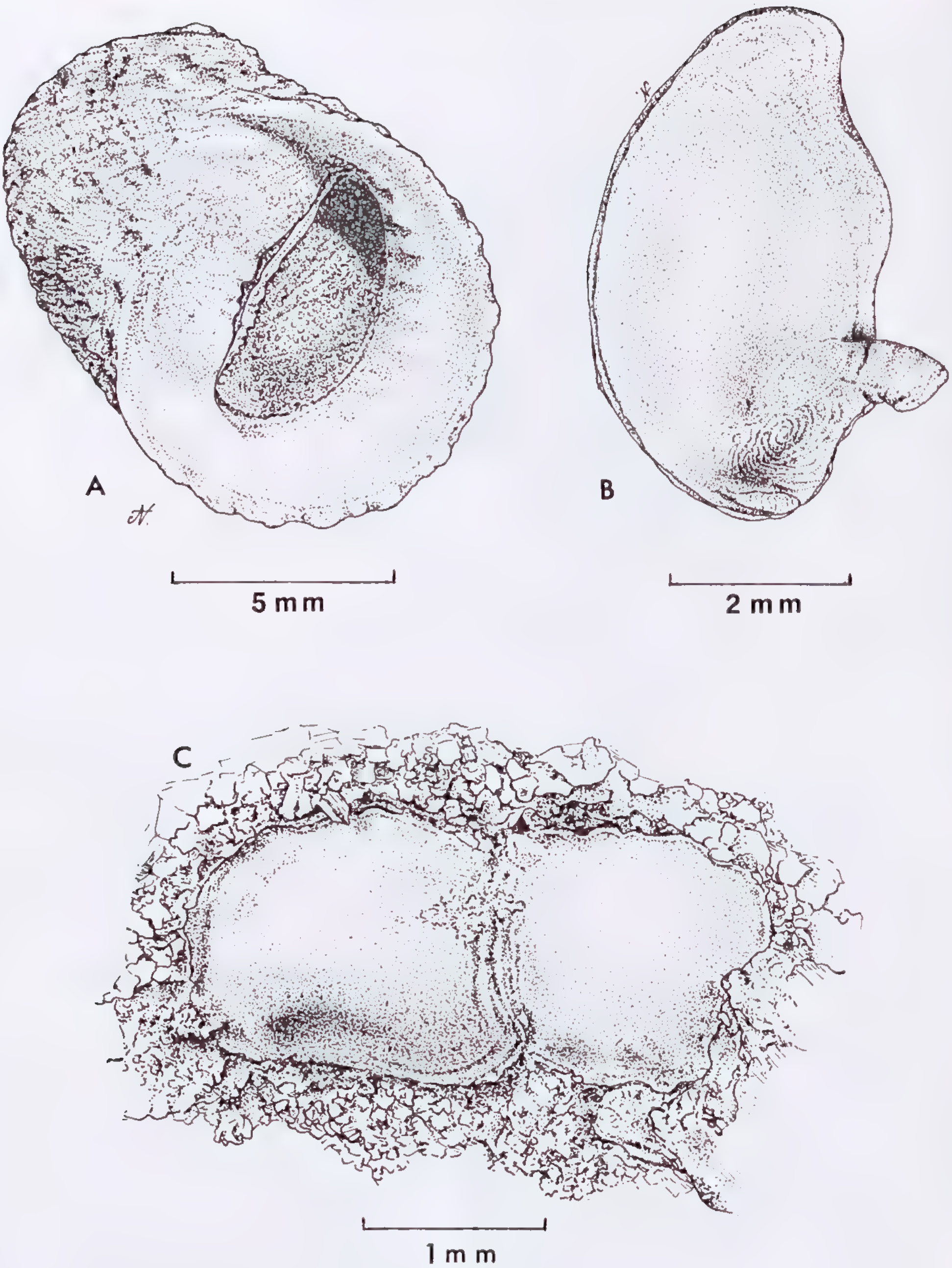

Fig. 4. *Nerita reticulata.* **A**, apertural view; **B**, internal face of the operculum; **C**, two egg capsules.

the apical edge of the upturned face. The escape opening measures 2 x 1.2 mm. The opposite face has a faint, rounded projection at the central part of the apical edge, opposite the escape opening. Most of the interior of the egg capsule is occupied by a viscous filamentous mass. The exact number of eggs in a single capsule could not be counted, but appeared to vary between 20 and 50. The egg diameter varies between 600 and 700 µm, suggesting direct development. This is corroborated by the relatively large size of the escape opening.

Comparative remarks. The present sample is very similar to egg capsules from other regions assigned to members of the family Melongenidae. The egg capsule of *Melongena*

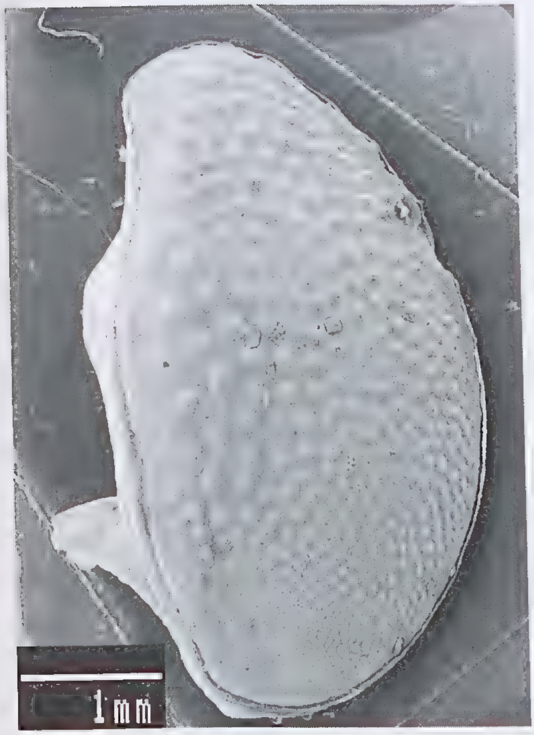

Fig. 5. *Nerita reticulata*. External face of the operculum.

corona (Gmelin, 1791: 3552) from the Caribbean region was described and figured by Perry and Schwengel (1955: 166, pl. 52, fig. 351 a-c) and by Clench and Turner (1956: 162, pl. 95, figs 1, 2). In *M. corona* the apical corners are less prominent, but the escape opening has the same characteristic as the present egg capsules. The number of eggs of *M. corona* varies from 50 to 120 and the development is stated to be direct. D'Asaro (1970: 40, fig. 4) described and figured the egg capsule of *Melongena patula* (Broderip and Sowerby, 1829: 377) from the Panamic region. It is likewise very similar to the present egg capsules.

Few specimens of *Pugilina cochlidium* were present at the collecting site, supporting the specific assignment.

Habitat. The egg capsules were collected on a sandflat exposed at low water. They were deposited on a piece of dead coral and worm tubes.

Distribution. *Pugilina cochlidium* ranges from northern Australia into the Indian Ocean. It has also been recorded from Indonesian waters. In Australian waters it ranges from the Kimberleys to northern Queensland.

Nassariidae Iredale

Wilson (1994: 75) included the family as a subfamily of Buccinidae.

Remarks. The identification of the present two species of Nassariidae is based on the monograph of Cernohorsky (1984). The egg capsules and reproductive strategy of a number of taxa of the family have been described in numerous papers. The following are singled out. Amio (1963) gave a detailed study of five species from Japanese waters. Cernohorsky (1984) gave a comprehensive survey of the reproductive strategy of the family and figured the egg capsules of 28 taxa (out of 319 Recent taxa). D'Asaro (1993) presented detailed morphological descriptions of 28 taxa, of which 26 are figured. The egg capsules are divided into four morphological categories. D'Asaro paid attention to the problem of the use of egg-capsule morphology as a species-specific character and concluded that this is not always the case.

In contrast to, for instance, the Neritidae, nassariid egg capsules are extremely variable, as is also the reproductive strategy. Thus, in the Nassariidae the number of eggs per capsule varies from 1 to 300, and the egg size varies from 50 to 700 µm. Nurse eggs occur in some species and few taxa have acquired ovoviviparity (D'Asaro 1993). Pelagic as well as direct development occur in the family.

Nassarius (Zeuxis) dorsatus (Röding, 1798)

(Fig. 8)

Buccinum dorsatus Röding 1798: 111.

Nassarius (Zeuxis) dorsatus (Röding, 1798). - Cernohorsky 1981: 165, figs 50-53; -1884: 54; - Wells and Bryce 1988: 99, figs 347-348; - Wilson 1994: 87, pl. 14, fig. 23a-e.

Material. Mandorah, Cox Peninsula, Darwin Harbour, 14 and 17 July 1993, 26 specimens (ZMUC).

Remarks. Cernohorsky (1981) designated Darwin, Northern Territory as the type locality.

All specimens of the sample had the protoconch and the upper whorls of the teleoconch covered by a white crust. The shell may attain a length of 40 mm; the largest specimen of the present sample has a length of about 20 mm.

The specimens were kept alive in a tray with sea water and sediment from the place of collecting. No egg capsules were produced. D'Asaro

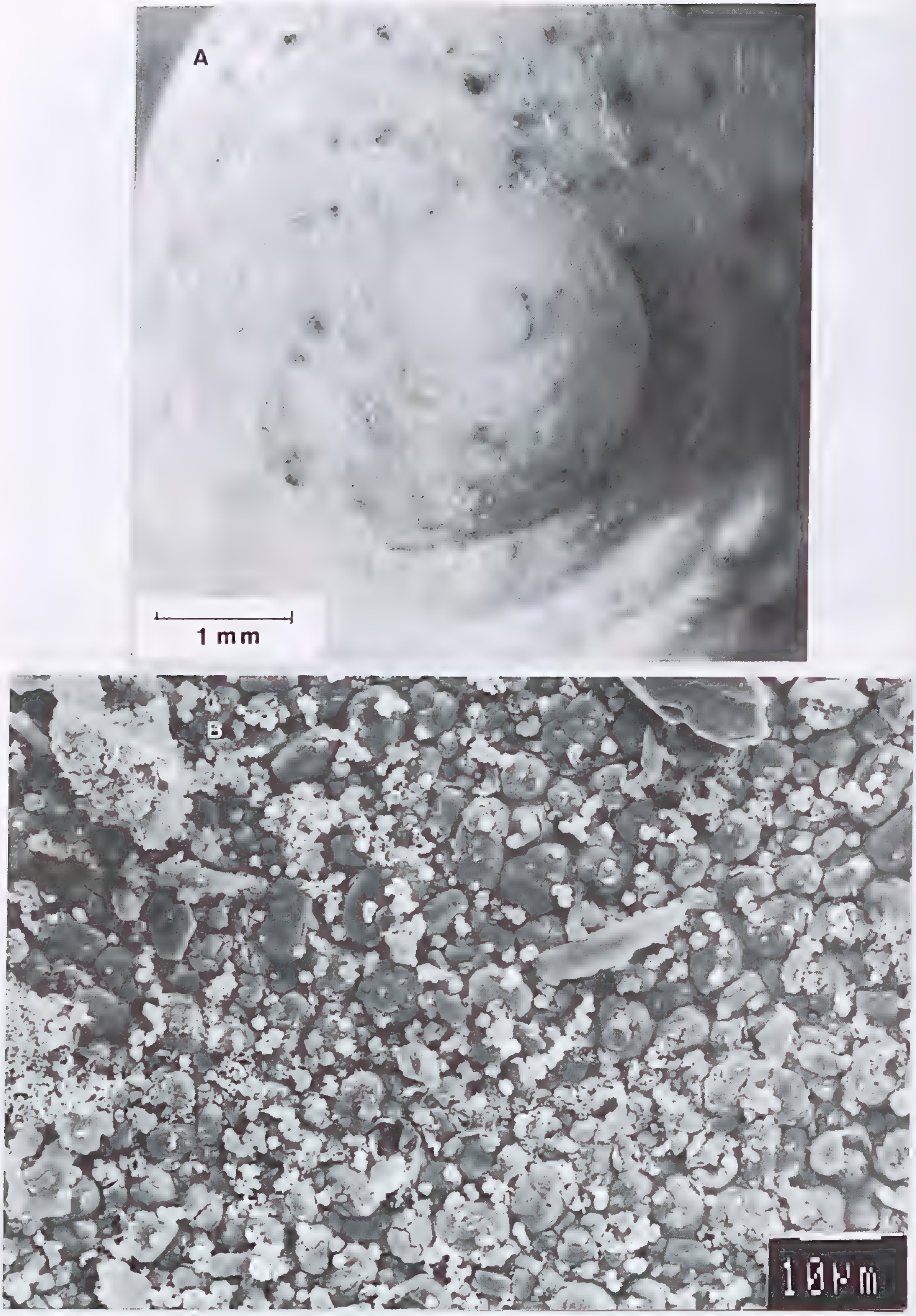

Fig. 6. *Nerita reticulata.* **A**, detail of the protoconch and upper whorls of the teleoconch; **B**, reinforced bodies of an egg capsule.

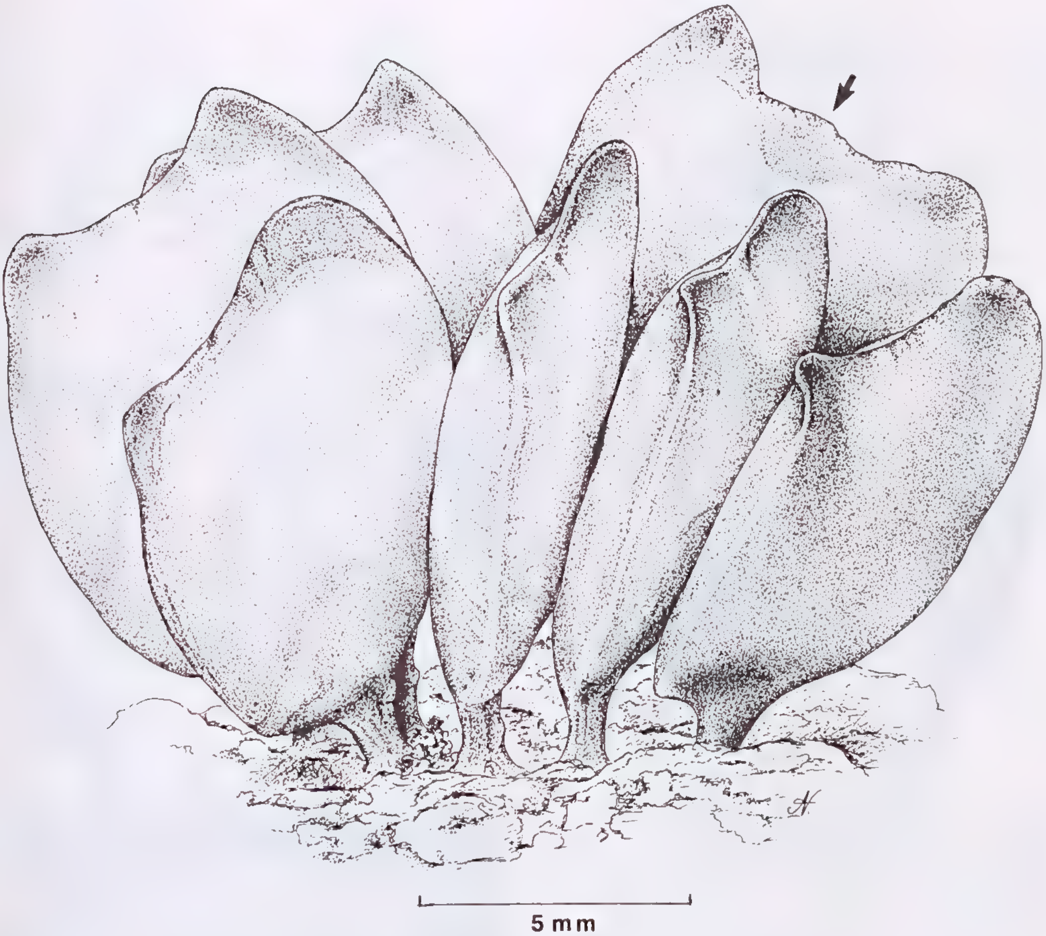

Fig. 7. *Pugilina cochlidium*. Egg capsules. The arrow points to the elliptic escape opening.

(1993) described and figured the egg capsules of *N. dorsatus* collected at Coorooman Creek, Queensland. The rounded triangular egg capsule has a height of about 500 µm, thus very small in proportion to the size of the parent. D'Asaro's (1993) figure is reproduced here as Figure 8.

Habitat. Cernohorsky (1981) stated that *N. dorsatus* occurs on reefs and mud flats. The present specimens were collected on a beach with pure sand at low tide. The animals were abundant, moving around vigorously, particularly in the small channels with outflowing water.

Distribution. From Exmouth Gulf, Western Australia (about 20°S), northwards, extending to the northern part of New South Wales. It extends to the southern coast of New Guinea.

Nassarius (Zeuxis) fraudator Cernohorsky, 1980
(Figs 9-10)

Nassarius fraudator Cernohorsky, 1980: 141, figs 12-17.

Nassarius (Zeuxis) fraudator Cernohorsky, 1981: 172, figs 63-65; -1984: 150, pl. 30, figs 5-7; - Wilson 1994: 87, pl. 15, fig. 20a-b.

Material. Fannie Bay, Darwin Harbour, 12 July 1993, 34 specimens (ZMUC).

Remarks. At the collecting site the animals moved along vigorously, nearly completely buried in soft sediment. All specimens had their shell completely covered by a rather solid brown deposit, leaving only the aperture free. The shell sculpture appeared after the deposit was removed with a brush.

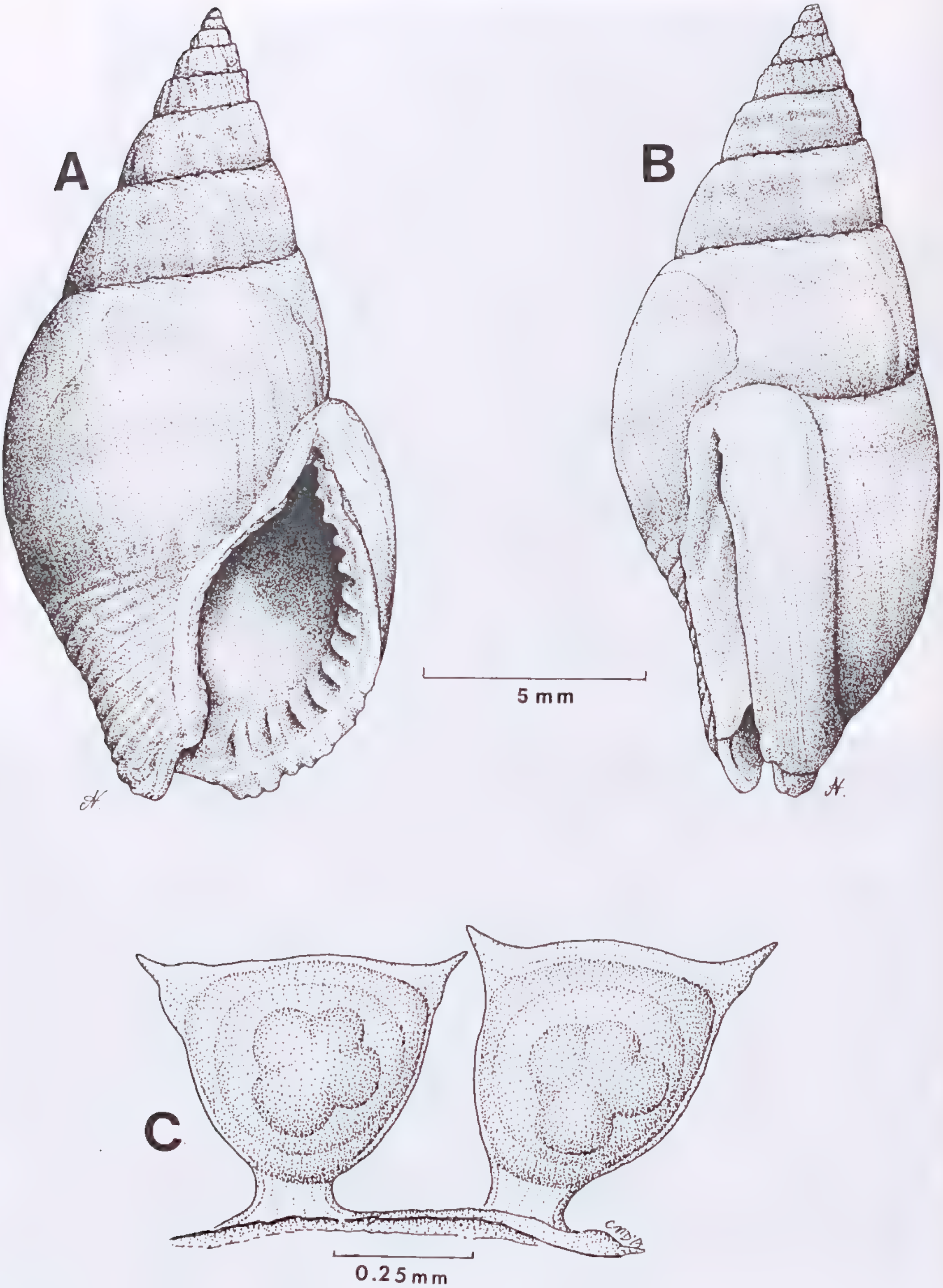

Fig. 8. *Nassarius (Zeuxis) dorsatus.* **A**, apertural view. **B**, lateral view. **C**, egg capsules (after D'Asaro 1993).

About 15 specimens were kept alive in a jar (about 1 liter). On 17 July 1993 numerous egg capsules were observed fastened to the glass. Several hundred capsules were placed close together, arranged in curved rows, each with 10-15 capsules. The actual spawning was not observed, but small differences in capsule morphology may indicate communal spawning. The egg capsule of *Nassarius fraudator* has not been described before.

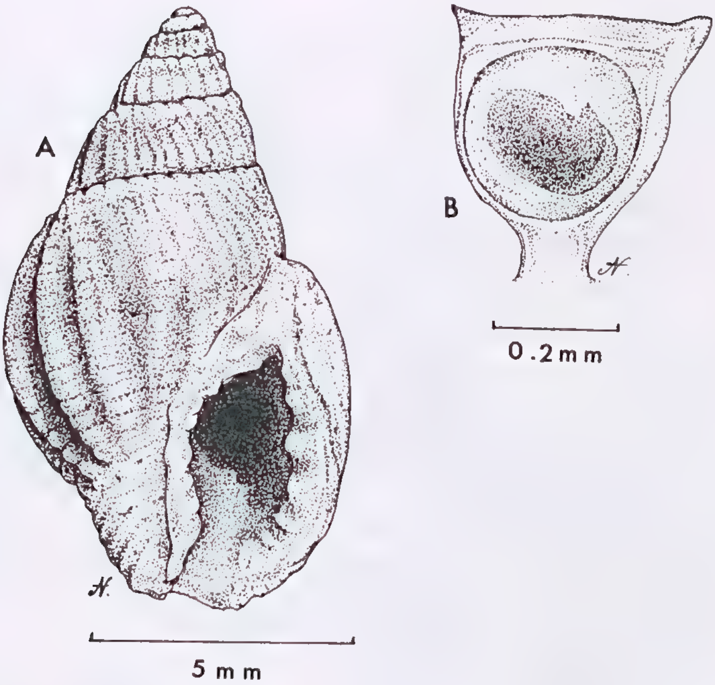

Fig. 9. *Nassarius (Zeuxis) fraudator.* **A**, apertural view. **B**, egg capsule.

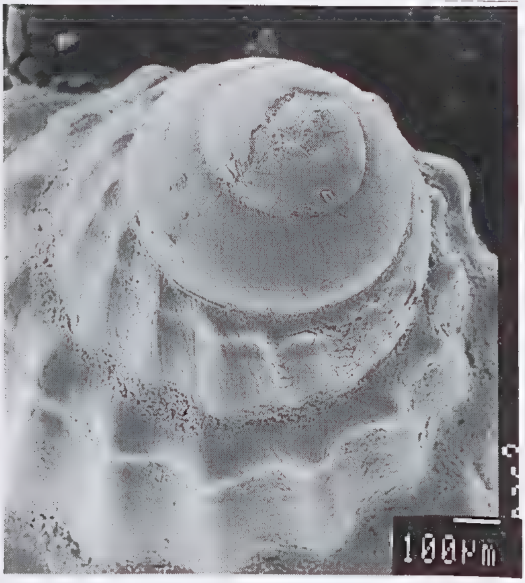

Fig. 10. *Nassarius (Zeuxis) fraudator.* Detail of the protoconch and upper whorls of the teleoconch.

Description. *Shell.* The largest shells (Fig. 9A) of the present sample measured 13.5 mm. They have strong axial ribs, as has also the paratype from the Darwin region figured by Cernohorsky (1980: fig. 15; 1981: fig. 65; 1984: fig. 7). Additionally, there is a fine spiral sculpture; the aperture is strongly dentate. The protoconch (Fig. 10) has two and a half smooth whorls. A distinction between protoconch I and II could not be observed.

Operculum. The operculum is horny, yellowish brown and transparent. The tentacles are stout at the basal part, but become slender and pointed distal to the eye. Two pointed tentacles are present at the posterior end of the foot.

Egg capsule. The egg capsule (Fig. 9B) is a flattened pouch, measuring about 400 µm in height. It is triangular with pointed upper corners. No escape opening is present. The stalk is very short. Each egg capsule contains a single egg. At the time of preservation (20 July) the larvae had attained the trochophore stage with incipient shell formation. The length of the embryo was about 210 µm.

Habitat. The animals were abundant on a sandflat exposed at low water.

Distribution. From Exmouth Gulf, Western (about 22°S), northwards and eastwards to Cape York and the south coast of New Guinea around Port Moresby (about 147°E). Wilson (1994) states that *N. fraudator* is not common.

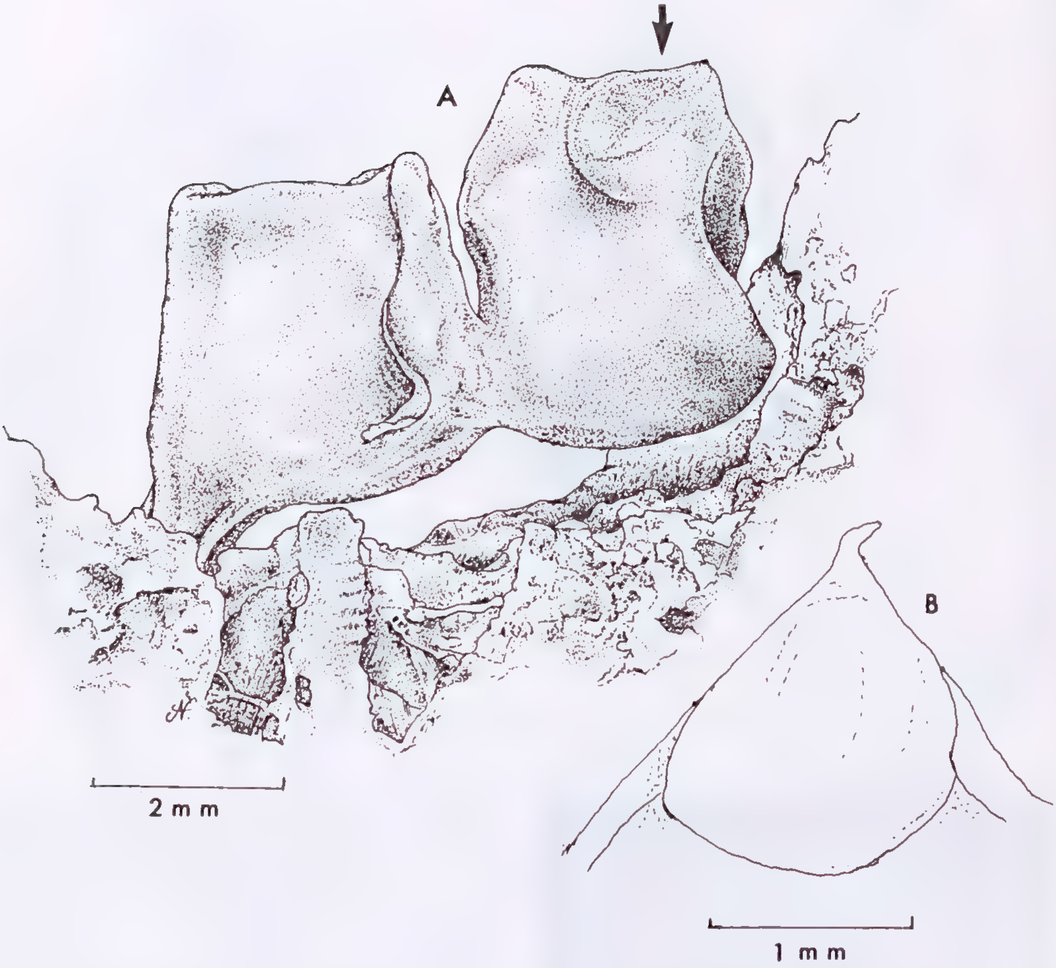

Fig. 11. ?*Cronia margariticola*. Egg capsules. The arow points to the prominent escape opening.

Muricidae Rafinesque

Cronia margariticola (Broderip, 1833)

(Fig. 11)

Murex margariticola Broderip, 1833: 177.

Cronia margariticola Wells 1978: 279: 1980: 243; - Kilburn and Rippey 1982: 88, pl. 119, fig. 10; - Cernohorsky 1982: 116, figs 15-18; - Wells and Bryce 1988: 92, pl. 27, fig. 310; - Wilson 1994: 22, pl. 5, fig. 23a-d.

Material. Mandorah, Darwin Harbour, 14 July 1993, 2 egg capsules (ZMUC).

Description of egg capsule. The egg capsule has a flat and a convex face, the latter with a prominent longitudinal edge ending at the pointed apical part. Some secondary ribs are present. The prominent escape opening is located on the flat face, just below the apical point. The peduncle is short with four or five sharp supports. The interior was occupied by a filamentous mass with only a few eggs, each measuring about 250 µm in diameter.

Remarks. The egg capsules appear to be hitherto unknown. They were collected at a site where *Cronia margariticola* was common. The egg capsule of the species mentioned is unknown. Hence the present egg capsules are provisionally assigned to *C. margariticola*.

Habitat. Wells (1978) stated that *C. margariticola* is the most abundant species in the low intertidal zone. It is very common on rocky coasts around Darwin.

One of the egg capsules was attached on a piece of coral, the other was attached to the top of the lower one, partly covering its escape opening with its basal plate.

Distribution. *Cronia margariticola* has a wide distribution, being recorded from Natal, where it is common, to Fiji; it does not extend to Hawaii or Fanning Island. In the western Pacific it extends to the central part of Honshu, Japan. At Australia it is known from Northwest Cape (about 22°S) along the west and north coasts to northern New South Wales.

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Accepted: 1 August 1995

A REVIEW OF THE NORTHERN AUSTRALIAN SPECIES OF THE GENERA *CASSIDULA* AND *ELLOBIUM* (GASTROPODA: ELLOBIIDAE).

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ABSTRACT

The northern Australian species of the ellobiid genera *Cassidula* (six species) and *Ellobium* (two species) are reviewed. Several modifications are made to the previously reported ranges of northern Australian *Cassidula*. Although recorded in the literature, *Ellobium aurismidae* Linnaeus, 1767, cannot be confirmed as living in the region. The known range of *Ellobium semisculptum* H. and A. Adams, 1854, is extended west to Western Australia. Radulae of six species are described and figured.

Keywords: Taxonomy, Gastropoda, Ellobiidae, *Cassidula*, *Ellobium*, northern Australia

INTRODUCTION

The Ellobiidae is one of the few pulmonate families to occur in marine environments. They occupy a wide range of habitats which can be grouped into four ecological categories: estuarine, marine intertidal, coastal terrestrial and inland terrestrial (Morton 1955a), and may be common and ecologically important in these areas. Morton (1955a) provided a broad general survey of the functional morphology, particularly the reproductive and digestive systems, of the family and investigated evolutionary relationships within the family with other groups in the Gastropoda. Morton (1955b) studied in detail three British ellobiid species representing three different genera.

The taxonomy of ellobiids is problematic on a world-wide scale. The group is most diverse in the Indo-Pacific, including Australia, but few studies of their systematics have been undertaken. Van Benthem Jutting (1952) revised the ellobiids of the Indonesian island of Java and its satellite islands. There have been no reviews of Australian ellobiids. Smith (1992) provided a detailed listing of the known non-marine molluscs of Australia and included the Ellobiidae because of the supralittoral to semi-terrestrial habitat of some species. Smith listed 37 species belonging to 11 genera, and pointed out the substantial need for revisionary work on Australian members of the family. Martins (1992) recently revised the subfamily Pedipedinae in Hong Kong and Martins and Tristao da Cunha (1992) provided information on the comparative ecology of ellobiids in a salt marsh and on a rocky shore in Hong Kong.

The present paper revises the northern Australian species of the genera *Cassidula* and *Ellobium*. It was prompted by work in Hong Kong mangroves during which *Ellobium chinense* and *E. polita* were collected. These two species are similar in shell characters and occupy the same habitats as *E. aurisjudae* and *E. aurismidae* which have been recorded from northern Australia, leading to the question of whether they are in fact two species or four. Two eastern Australian species of *Cassidula, C. granosula* (Iredale, 1936) and *C. zonata* H. and A. Adams (1855) are not considered here.

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MATERIALS AND METHODS

Ellobiids were specifically collected for this paper during field work in the area of the Darwin, Northern Territory, in 1986 and during the Sixth International Marine Biological Workshop in 1993 and deposited in the Museum and Art Gallery of the Northern Territory (NTM) and the Western Australian Museum (WAM). Collections were made in the Kimberley region of Western Australia during field expeditions in 1988 and 1991 and in the Montebello Islands, WA, in 1993, and deposited in the WAM. Existing collections of the WAM, the Australian Museum, Sydney (AMS) and the Queensland Museum, Brisbane (QM) were also examined, and available type material was borrowed from the Museum National d'Histoire Naturelle, Paris (MNHN). Synonymies are not intended to be complete; they are restricted to major synonyms and Australian references. Descriptions are based on shells facing the viewer, aperture up.

Abbreviations are: L, length; W, width; A, aperture. Scanning electron micrographs of radulae were made using standard techniques.

SYSTEMATICS

Family Ellobiidae
H. and A. Adams (in Pfeiffer), 1854
Subfamily Pythiinae Odhner, 1925

Description. Primitive subfamily, little internal shell resorption, habitat original high tidal or estuarine (Morton 1955a).

Genus *Cassidula* Ferussac, 1821

Type species. *Bulimus aurisfelis* Bruguière, 1789, subsequent designation by Gray (1847). *Melosidula* Iredale, 1936.

Generic description. Primitive genus, stomach primitive, gizzard wall muscular, strong but never massive; excurrent grooves from digestive diverticula converge to form strongly ciliated intestinal groove; posterior digestive diverticulum lost; posterior lobe of digestive gland fused with anterior; single hermaphroditic duct; vas deferens moves forward from female opening to male genital pore as closed tube sunk beneath integument; axial pillar lost through resorption; thin spiral lamellae retained and cuts spiral groove through visceral mass; foot simple undivided disk (Morton 1955a).

Shell small to medium, 10 to 30 mm long as adults. Protoconch minute but usually worn away. Spire very low to medium height, triangular in outline with whorls rapidly increasing in diameter; upper surface of spire whorls much smaller than lower surface. Suture narrow, thin, may be slightly channeled. Body whorl with medium to strong shoulder. Shell surface variable, smooth to heavily rugose. Whorls rounded. Varices absent in all species. Aperture elongate, mouth heavily callused, narrow with two strong parietal folds and strong columellar fold. Outer lip notch and swelling present. Shell colour variable, brown, brown with yellow spiral lines, or gray. Aperture may be white or orange. Tropical Indo-Pacific. Common in many mangrove areas.

Cassidula aurisfelis (Bruguière, 1789)
Plate 1, Fig. 1 and Plate 2, Figs 1-2.

Bulimus aurisfelis Bruguière, 1789: 343, pl. 460, fig. 3.

Cassidula (*Cassidula*) *aurisfelis* (Bruguière, 1789); - Smith 1992: 212.

Dautzenberg and Fischer (1905: 108-110) present a detailed synonymy of this species, which is not repeated here. Only subsequent Australian references are given.

Rhodostoma aurisfelis (Bruguière). - Iredale, 1914: 667,675; - Hedley, 1916: 215; - Allan 1940: 198, figured.

Cassidula aurisfelis (Bruguière). - Abbott and Dance 1982.

Location of types. Presumed lost (Smith 1992).

Type locality. Unknown (Smith 1992).

Distribution. Western Pacific: Barrow Island, Western Australia to Yeppoon, Queensland.

Material examined. *Western Australia*: WA (AMS); Barrow I. (WAM); Montebello Is. (2 lots AMS; 2 lots WAM); Broome (3 lots AMS); Willie Creek, 24 km N of Broome (AMS); Coast near Wallall, 32 km S of Broome (AMS); Roebuck Plains (AMS). *Queensland*: Torres Str. (AMS); Banks I. (Moa I.), Torres Str. (AMS); Annan R, S of Cooktown (AMS); Machan's Beach, N of Cairns (AMS); 1 km W of mouth of Ross R., Townsville (AMS); Sinclair Bay (AMS); Conway Beach, Proserpine (AMS); Keppel Sands, near Yeppoon (AMS). *Papua New Guinea*: (AMS); Kotavake Village, Gulf Prov. (AMS); New Britain (QM); Samarai (QM). *Borneo*: Beach 14 km N of mouth of Mahakam R.,

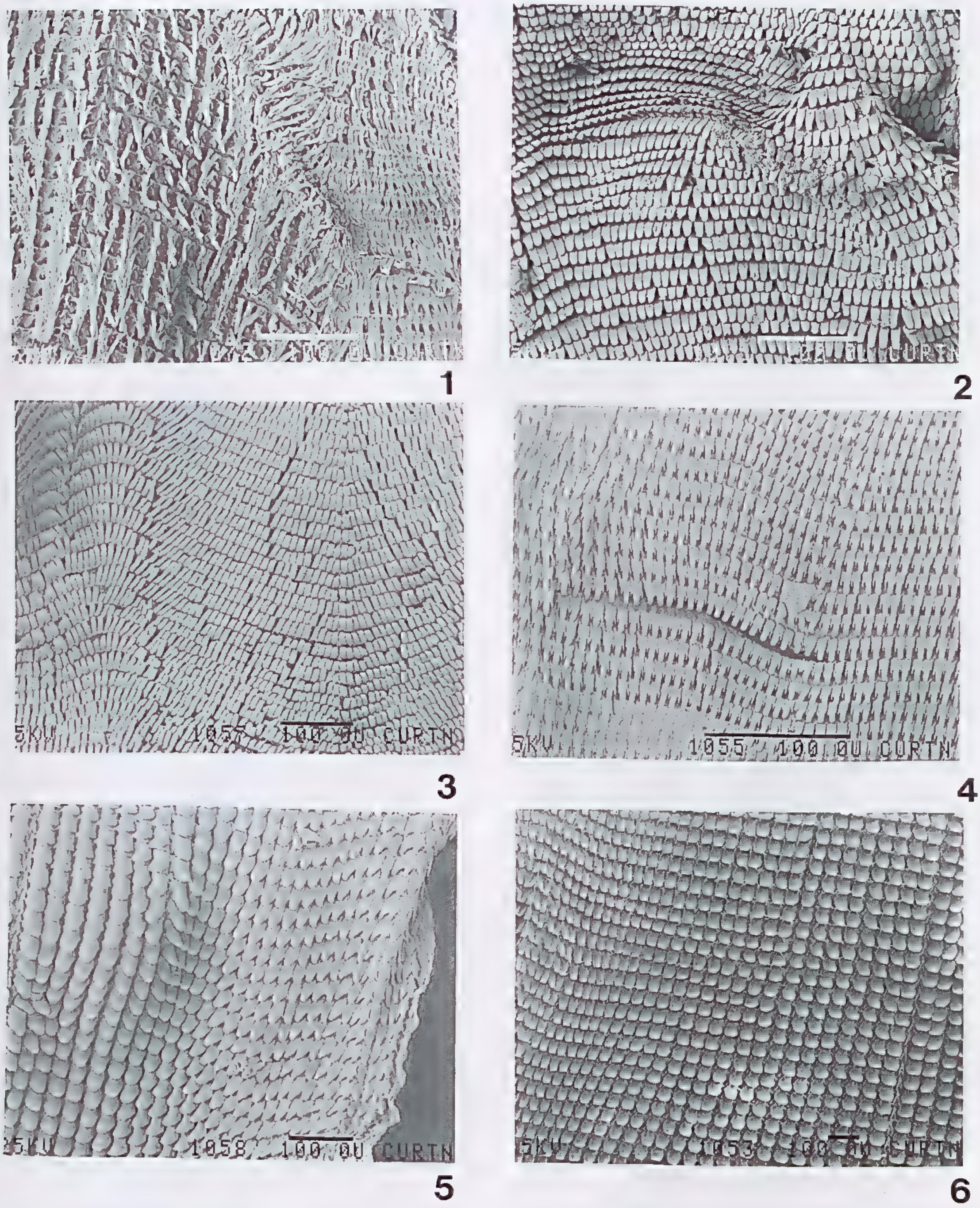

Plate 1. Radulae of *Cassidula* and *Ellobium*. **1.** *Cassidula aurisfelis* (Bruguière, 1789). **2.** *C. angulifera* Petit de la Saussaye, 1841. **3.** *C. rugata* (Menke, 1843). **4.** *C. doliolum* (Petit, 1842). **5.** *Ellobium aurisjudae* (Linnaeus, 1758). **6.** *E. aurismidae* (Linnaeus, 1767).

E. Kalimantan, E. Borneo (AMS); Sarawak (QM).

Description. *Shell.* Shell large for genus, to 30 mm, heavy (Table 1). Protoconch small, low, 0.50 mm wide, broken off. Spire low, triangular. Teleoconch of seven rapidly expanding whorls. Spire whorls rounded, slight shoulder at centre, lower margin of whorl much larger than upper, surface of whorl smooth except for fine axial growth striae. Suture distinct, slightly channeled, slightly irregular. Body whorl large, indistinct shoulder, surface smooth

Table 1. Measurements of the shells of *Cassidula aurisfelis* from Montebello Is., WA.

	Length	Width	Aperture	W/L	A/L
$\bar{X}$ (n=62)	26.2	15.9	14.9	0.61	0.57
1 S.D.	1.9	1.3	1.2 0	0.02	0.02
Range	21.5-30.2	13.6-18.2	11.7-18.2	0.57-0.65	0.53-0.61

except for numerous axial growth striae crossed by fine spiral striae, presenting microscopic crosshatching. Outer lip heavily thickened, straight, with strong, low broad fold in centre. Fold with five very fine ridges. Two slight ridges on inner side of outer lip above fold, slight notch below. Columella strongly thickened with strong narrow ridge down centre of lower part of body whorl, extending around bottom of shell. Inner surface of aperture with three pronounced folds: posterior parietal fold narrow, pointed downwards, anterior parietal fold broader, columellar fold broad and bifurcated. Anterior end of shell is rounded with strong thickening. Colour of outer shell uniform dark gray, may be lighter on shoulder, lighter on spire. Outer lip and apertural surfaces off-white.

Radula. Rachidian tooth small, wishbone shaped, 18 µm high, 6 µm wide, with upper end and lower flares capped and strengthened. Lateral teeth grade into marginals with no clear distinction, both very irregular in appearance. About 40 teeth per half row, all long, narrow (45 µm high, 6 µm wide), easily twisted during preparation, project above basal plate.

Remarks. Abbott and Dance (1982) and Smith (1992) recorded this species from northwestern Western Australia. Although there are few records, its range is here extended to include Queensland as far as Yeppoon. *Cassidula aurisfelis* has not been recorded in the Northern Territory, and it is not known whether the lack of records reflects a disjunct distribution or simply a lack of collections.

Cassidula angulifera
Petit de la Saussaye, 1841

Plate 1, Fig. 2 and Plate 2, Figs 3-4.

Auricula angulifera Petit de la Saussaye, 1841: 101; - Menke 1843: 8.

Cassidula angulifera (Petit) - Bednall 1876: 114; - Brazier 1877 (1878): 129; 1878: 275; - Tenison-Woods 1880: 121; - Cernohorsky 1972.

Rhodostoma angulifera (Petit) - Hedley 1916: 215; - Allan 1940: 198, figured; - Rippingale and McMichael 1961: 154, pl. 21, fig. 20.

Cassidula (*Cassidula*) *angulifera* Petit de la Saussaye - Smith 1992: 212.

Location of types. Syntype, MNHN.

Type locality. Unknown (Smith, 1992) (Listed on MNHN label as 'Nov. Zeland').

Distribution. Shark Bay, Western Australia to Sarina, Queensland.

Material examined. *Western Australia*: Gladstone, Shark Bay (WAM); Gales Bay, Exmouth Gulf (WAM); Bay of Rest, Exmouth Gulf (22°18'S; 114°07'E) (WAM); Port Hedland (WAM); Broome (2 lots WAM); St. George Basin, Prince Regent R. (WAM); Prince Regent R. (WAM); Careening Bay, Kimberley (15°06'S; 125°00'E) (WAM); Munja Station, Walcott Inlet (AMS); Mitchell Plateau (WAM); Port Warrender, Admiralty Gulf (8 lots WAM). *Northern Territory:* Darwin area: Darwin (QM); S. Alligator R. (2 lots NTM); 14 km from mouth, Adelaide R. (NTM); Gunn Point (NTM; 2 lots WAM); Cox Peninsula (NTM; 2 lots WAM); Rapid Creek (2 lots NTM; WAM); Creek H, Darwin Harbour (NTM; 2 lots WAM); East Point, (AMS); Port Darwin (AMS); Sadgroves Creek (WAM); Tree Point (AMS); Mindil Beach (AMS); Dinah Beach Darwin (AMS); Shoal Bay, NE of Darwin (2 lots AMS); Western Headland, Port Keats (AMS); Cape Condor, Melville I. (AMS); Andranango Creek, Melville I. (11°21'S; 130°54'E) (AMS); Cape Condor, Melville I. (AMS); Port Essington (AMS; WAM); Cape Bedwell, W of Cape Don (AMS); Palm Bay, Croker I. (AMS; WAM); Croker I. (2 lots AMS); Crab Creek, Boucat Bay, Arnhem Land (AMS); Yirrkala Mission (AMS; WAM); Djigagila Creek, Arnhem Land (12°09'S; 134°49'E) (AMS); Buckingham R. (12°31'S; 135°43'E) (AMS); Peter John R., Arnhem Land (12°12'S; 136°24'E) (AMS). *Queensland:* Karumba (AMS); Norman R., Karumba (AMS); Mapoon (AMS); W end Saibai Village, Saibai I., Torres Str. (AMS); Saibai I. (QM); Cape York (2 lots AMS); Starcke R. (AMS); St. Lawrence, N of Cooktown (AMS); Cooktown (2 lots AMS); Annan R. (AMS); Mt Alexander, Mossman (AMS); Mossman (AMS; QM); Low Isles near Port Douglas (AMS; QM); Port Douglas (QM); Machan's Beach, N of

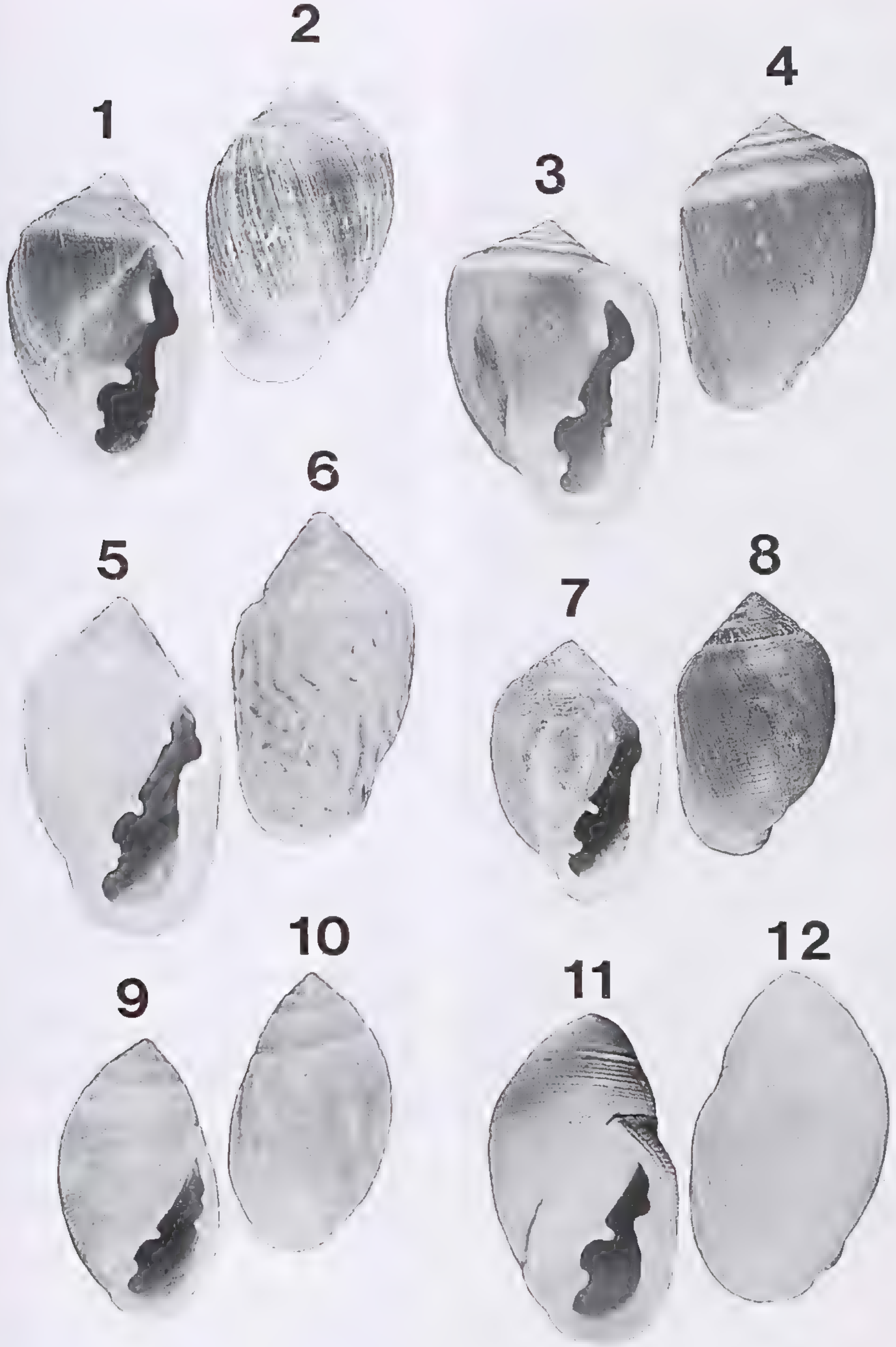

Plate 2. Shells of *Cassidula*. **1-2.** *C. aurisfelis* (Bruguière, 1789). Montebello Is., W.A., WAM 116-94. **3-4.** *C. angulifera* Petit de la Saussaye, 1841. Port Essington, N.T., WAM 113-94. **5-6.** *Cassidula rugata* (Menke, 1843). Port Essington, N.T. , WAM 115-94. **7-8.** *C. nucleus* (Gmelin, 1791). Port Essington, N.T., AMS C.300075. **9-10.** *C. doliolum* (Petit, 1842). Lady Elliot I., Qld., AMS C.8830. **11-12.** *C. sowerbyana* (Pfeiffer, 1853). Broome, W.A. (17°58'S; 122°14'E), AMS C.300077.

Cairns (AMS); Green I., off Cairns (QM); Cairns (AMS; 2 lots QM); Cardwell (QM); 1 km W of Ross R. mouth, Townsville (2 lots AMS); Magnetic I. (3 lots AMS; 2 lots WAM); Cape Cleveland, E of Townsville (QM); Sinclair Bay near Bowen (AMS); Bowen (3 lots AMS; QM); Lindeman I., Whitsunday Passage (AMS); Port Mackay (3 lots AMS; NTM); Sarina Beach (21°24'S; 149°19'E) (AMS); 128 km S of Sarina (AMS).

Description. *Shell.* Shell large for genus, up to 32 mm, spire very low, triangular. Protoconch small, low, 0.70 mm wide, broken off. Teleoconch of eight rapidly expanding whorls. Whorls with slight shoulder at centre, lower surface much larger than upper, surface smooth except for axial growth lines. Body whorl usually with strong shoulder, surface smooth except for axial growth lines crossed by fine spiral striae, giving microscopic cross-hatched appearance. Outer lip strongly thickened. Upper surface with two low, round ridges. Substantially increased thickening begins about one third down outer lip, continues down entire inner surface of aperture to base, has several low ridges on its surface but no strong folds. Outer lip inner swelling on lower surface of inner lip continues along base of shell. Columella has three strong folds: posterior parietal fold narrow, points downward, anterior parietal fold narrow, high, pointing slightly downwards, columellar fold broad and bifurcated. Shell colour light brown, darker near margins, shoulder yellow on body whorl and appearing as thin yellow line on upper whorls, aperture off-white.

Radula. Rachidian tooth minute, wishbone shaped, 10 µm high, 6 µm wide, difficult to see between lateral teeth. Lateral teeth grade into marginals with no clear distinction, inner teeth small, rectangular with rounded ends, 20 µm long, 10 µm wide. In excess of 50 teeth per half row. Marginal teeth develop small cusps on base of each side of the tooth.

Remarks. Smith (1992) recorded this species from the Northern Territory to Queensland. Although there are few records available, the range of *Cassidula angulifera* is here extended throughout the tropical portions of Western Australia. *Cassidula angulifera* (mean length 28 mm) is similar in size and appearance to *C. aurisfelis* (mean length 26 mm), and the two occupy similar habitats and overlap geographically. I have never found both in the same mangrove community, though it is possible that the two are locally sympatric. They are very similar but can be distinguished using the following shell characters: *Cassidula angulifera* has a strong angular shoulder, lacking on *C. aurisfelis*, and the central region of the outer lip of *C. aurisfelis* has a distinct tooth which is lacking on *C. angulifera*, and where instead there is a broad outer lip inner swelling which is continuous down the lower two thirds of the inside of the aperture.

In addition, the radula of the two species is very different. The rachidian tooth of *C. aurisfelis* is nearly twice as high as in *C. angulifera* (18 vs. 10 µm). The lateral teeth of *C. aurisfelis* are long and narrow (45 µm high, 6 µm wide) and are easily twisted during preparation, while those of *C. angulifera* are more rounded and regular in shape with a length of 20 µm and a width of 10 µm.

Cassidula rugata (Menke, 1843)

Plate 1, Fig. 3 and Plate 2, Figs 5-6

Auricula rugata Menke, 1843: 8.

Cassidula rugata (Menke) - Tate 1881: 388-389; - Rippingale and McMichael 1961: 154, pl. 21, fig. 19; - Abbott and Dance 1982.

Rhodostoma rugata (Menke) - Allan 1940: 198, figured.

Cassidula (*Cassidula*) *rugata* (Menke) - Smith 1992: 212.

Location of types. Presumed lost (Smith 1992).

Type locality. Victoria River, Northern Territory (Smith 1992).

Distribution. Melville Island, Northern Territory to Port Mackay, Queensland.

Table 2. Measurements of shells of *Cassidula angulifera*.

	Length	Width	Aperture	W/L	A/L
Syntype, MNHN	30.6	22.0	19.7	0.72	0.64
Sadgroves Creek, Darwin (n=100) (WAM)					
Mean	28.0	19.0	18.2	0.67	0.64
S.D.	0.4	0.7	1.1	0.02	0.03
Range	25.3-32.4	17.3-21.1	16.9-21.1	0.62-0.72	0.60-0.72

Material examined. *Northern Territory:* Madlow Beach, Shark Bay, Melville I. (11°32'S; 130°35'E) (AMS); Dongau Creek, Melville I. (11°25'S; 131°23'E) (AMS); Andranango Creek, Melville I. (AMS); Cape Condor, Melville I. (AMS); Port Keats (AMS); Cox Peninsula (WAM); Darwin area: Darwin (QM); W. side Darwin Harbour (WAM); Gunn Point (NTM; WAM); Darwin (2 lots AMS); Casuarina Beach (NTM); Tree Point, SE of Darwin (AMS); Gunn Point (2 lots WAM; 2 lots NTM); Rapid Creek (WAM); Port Darwin (AMS); Dinah Beach (AMS); Adelaide R. (3 lots NTM; WAM); South Alligator R. (2 lots NTM); Madlow Beach, Shark Bay, Melville I. (11°32'S; 130°35'E) (AMS); Dongau Creek, Melville I. (11°25'S; 131°23'E) (AMS); Andranango Creek, Melville I. (AMS); Cape Condor, Melville I. (AMS); Port Keats (AMS); Boucat Bay, Arnhem Land (AMS); Yirrkala Mission (AMS; WAM); King R., W of Arnhem Land (AMS); King R., Arnhem Land (11°54'S; 133°27'E) (AMS); Bat I., Arnhem Land (12°06'S; 134°11'E) (AMS); Djigagila Creek, Arnhem Land (12°09'S; 134°49'E) (AMS); Dorbilla Creek, Arnhem Land (12°11'S; 134°53'E) (2 lots AMS); Gomoruru R., Arnhem Land (12°30'S; 136°13'E) (3 lots AMS); Peter John R., Arnhem Land (12°12'S; 136°24'E) (2 lots AMS). *Queensland:* Mapoon (AMS); N coast Qld (AMS); S of NW Creek, Prince of Wales I., Torres Str. (WAM); Machan's Beach, Cairns (WAM); Cairns (WAM); Port Mackay (AMS).

Description. *Shell.* Shell large for genus, up to 35 mm, spire low but strong, markedly triangular. Protoconch small, low, 0.70 mm wide, broken off. Teleoconch of up to eight rapidly expanding whorls. Whorls with slight shoulder at centre, lower surface much larger than upper, surface smooth except for axial growth lines. Body whorl with strong shoulder, surface heavily rugose with numerous strong, narrow, irregular axial ribs which begin at upper suture of body whorl and continue with wavy pattern to anterior tip of shell. Crossed by distinct spiral striae which are strong between axial ribs, worn off surface of ribs. Outer lip notch and outer lip inner swelling both strong; latter begins about one third down outer lip, continues down entire inner surface of aperture to base, has several low ridges on its surface. Strong thickening on lower surface of inner side of aperture continues along base of shell. Inner aperture has three strong folds: posterior parietal fold narrow, points downward, anterior parietal fold broader, larger, pointing slightly downwards, columellar fold broad and bifurcated. Shell colour light gray, darker near margins, aperture strong orangeish.

Radula. Rachidian tooth minute, wishbone shaped, 12 µm high, 7 µm wide, difficult to see between lateral teeth. Lateral teeth grade into marginals with no clear distinction, inner teeth small, rectangular with squarish ends, 25 µm long, 10 µm wide. In excess of 50 teeth per half row. Lateral teeth of similar shape and size to marginals.

Remarks. Smith (1992) recorded this species from Western Australia to Queensland. The only record from Western Australia is from Shark Bay in the Australian Museum; this needs to be confirmed. Abbott and Dance (1982) erroneously reported *C. rugata* from South Australia.

Cassidula rugata is slightly larger (mean length 31 mm) than *C. aurisfelis* (mean length 26 mm) and *C. angulifera* (mean length 28 mm), but the rugose back of the shell easily separates *C. rugata* from these species. Although the shells of some *C. rugata* are not very rugose, there is always some rugosity to the back of the shell.

Table 3. Measurements of shells of *Cassidula rugata*.

	Length	Width	Aperture	W/L	A/L
Mangroves on west side, Darwin Harbour (n=31) (WAM)					
Mean	31.1	18.0	18.8	0.58	0.60
S.D.	1.8	0.9	1.2	0.02	0.02
Range	27.5-34.5	15.9-19.5	15.5-20.5	0.54-0.62	0.56-0.67
Rapid Creek, Darwin (n=34) (WAM)					
Mean	31.0	17.7	18.9	0.57	0.61
S.D	1.4	0.8	1.1	0.02	0.02
Range	27.5-33.4	16.0-19.3	16.0-20.7	0.53-0.60	0.58-0.64

***Cassidula nucleus* (Gmelin, 1791)**
Plate 2, Figs 7-8

Helix nucleus Gmelin, 1791: 3651, no. 255.
Cassidula nucleus (Martyn) - Hedley 1912: 152.
Rhodostoma nucleus (Gmelin) - Allan 1940: 199, figured.
Cassidula (*Cassidula*) *nucleus* (Gmelin) -. Smith 1992: 213.

Location of types. Presumed lost (Smith 1992).

Type locality. Cooktown, Queensland (Smith 1992).

Distribution. Indo-Pacific: Port Essington, Northern Territory to Brunswick Heads, NSW.

Material examined. *Northern Territory, Australia:* Port Essington (AMS); Yirrkala Mission, Caledon Bay, NE Arnhemland (AMS); Cato R., Arnhem Bay (12°20'S; 136°40'E) (AMS); Liverpool R. mouth, Arnhem Estuary (AMS). *Queensland, Australia:* N end Yam I., Torres Strait (AMS); Yam I., Torres Strait (AMS); S side Thursday I., Torres Strait (AMS); Terry Beach, W side Prince of Wales I., Torres Strait (AMS); Cape York (AMS); Starcke R. (AMS); Annan R. (AMS); N side of Annan R. (AMS); Cooktown (AMS); Four Mile Beach, Port Douglas (4 lots AMS); Low Isles near Port Douglas (2 lots AMS); Dunk I., Rockingham Bay (AMS); Cardwell (2 lots AMS); Hayman I., Whitsunday Passage (2 lots AMS); Sinclair Bay, Cape Gloucester (AMS); Dingo Beach, Bowen (AMS); Bowen (4 lots AMS); Conway Beach, Proserpine (AMS); Boswell Creek, Yeppoon (AMS); Tin Can Bay, NE of Gympie (2 lots AMS); Peel I., Moreton Bay (2 lots AMS). *New South Wales, Australia*: Brunswick Heads (2 lots AMS). *Papua New Guinea:* (AMS); Collingwood Bay (AMS). *Indonesia:* (2 lots AMS). Mouth of Mimika R., Kokenaw, W. Irian (9°42'S; 136°05'E) (AMS). *Solomon Is:* (2 lots AMS). *New Caledonia:* (9 AMS). *Fiji:* (11 lots AMS). *New Hebrides:* (AMS). *Samoa:* (AMS). *The Philippines:* (14 lots AMS). *Sri Lanka:* (3 lots AMS). *India:*(AMS).

Description. *Shell.* Shell small to medium for genus, to 20 mm, low spire, shell rounded. Protoconch low, 0.25 mm wide, broken off. 8 teleoconch whorls. Whorls slightly rounded, lower surface much larger than upper. Suture slightly channeled, straight, distinct. Entire shell surface with fine spiral striae, margins crenulated, 8 on penultimate whorl, about 40 on body whorl, strong spiral ridge low on body whorl. Fine axial growth lines. Outer lip thickened, narrow channel at top of aperture, inner surface of outer lip with four strong folds, concentrated on upper part of aperture, third from top is largest. Inner surface of aperture strongly calcified on lower surface, rounded across bottom of shell. Inner aperture with two strong, narrow folds, anterior parietal just below midpoint, columellar lower down. Colour gray, broad lighter band below suture, also light bands on middle and lower surface of body whorl. Apertural surfaces off-white.

Radula. Not known.

Remarks. Smith (1992) recorded this species from Queensland and New South Wales. Only one record is available of the species in northernmost New South Wales, but there are numerous Queensland specimens. *Cassidula nucleus* also occurs in the Northern Territory at least as far west as Port Essington.

Cassidula nucleus is similar in colour to *C. doliolum*, and both have strong spiral striae. *Cassidula doliolum* can be distinguished by its smaller size (mean length 11 mm vs 17 mm for *C. nucleus*) and smaller anterior parietal and columellar folds on the inner margin of the aperture. In addition, *C. nucleus* has a regular

Table 4. Measurements of shells of *Cassidula nucleus.*

	Length	Width	Aperture	W/L	A/L
Hayman I., Whitsunday Passage, Qld (AMS C.90416) Adults only (n = 21)					
Mean	17.4	10.6	10.6	0.60	0.59
1 S.D.	1.9	1.0	1.1	0.02	0.02
Range	15.3-20.7	9.6-13.4	9.4-13.6	0.57-0.63	0.56-0.64
Cooktown, Qld (AMS C.28331) Adults only (n = 17)					
Mean	13.1	8.1	7.8	0.62	0.60
1 S.D.	0.7	0.5	0.5	0.02	0.02
Range	11.9-14.5	7.5-9.7	6.9-8.8	0.59-0.65	0.57-0.65

flat plate outer lip inner swelling compared to the narrower swelling and teeth present on *C. doliolum*.

Cassidula doliolum
(Petit de la Saussaye, 1842 [1843])
Plate 1, Fig. 4 and Plate 2, Figs 9-10

Auricula doliolum Petit, 1842: 201.

Cassidula doliolum (Petit) - Hedley 1913: 332.

Cassidula (*Cassidulta*) *doliolum* (Petit) - Smith 1992: 213.

Material examined. *Northern Territory, Australia:* Port Keats (AMS); Port Darwin (AMS); Dinah Beach, Darwin (AMS). *Queensland, Australia:* Weipa (AMS); 4 Mile Beach, Port Douglas (AMS); Townsville (AMS); Sinclair Bay, Cape Gloucester (AMS); Conway Beach, Proserpine (AMS); Gladstone (AMS); Quoin I., Port Curtis (AMS); Elizabeth Creek, Sarina (AMS); Sarina Inlet (AMS); Lady Elliot I. (AMS); Woody Point, Clontarf, Moreton Bay (AMS); Moreton Bay (AMS).

Description. *Shell.* Shell small for genus, to 12 mm, light. Protoconch low, small, 0.25 mm wide, broken off. Spire low, triangular. Eight straight-sided teleoconch whorls. Suture indistinct, narrow, nearly straight: slightly enlarged area just below suture. Lower margin of whorl much larger than upper. Body whorl with rounded shoulder, surface crossed by distinct spiral striae, seven on penultimate whorl, about 35 to 40 on body whorl. Numerous fine axial growth striae. Distinct narrow spiral ridge near anterior tip of shell. Aperture extends entire length of body whorl. Outer lip substantially thickened. Inner surface with narrow channel at upper end and two low swellings. Broad, flat plate begins about one third down shell, extending to top anterior tip of shell. Narrow ridge on inner surface of aperture extends to bottom of shell, and also extends around bottom. Inner surface of aperture with three folds, all small and narrow: posterior parietal fold points downwards; anterior parietal fold is very narrow and low on aperture, columellar fold is also narrow and not bifurcate. Shell colour gray darker just below suture. Aperture off-white.

Radula. Rachidian tooth minute, long, narrow, 10 µm high, 6 µm wide, difficult to see between lateral teeth. Lateral teeth grade into marginals with no clear distinction, at least 30 teeth per half row. Lateral and marginal teeth of uniform size and shape, 15 µm long, 7 µm wide, long, rectangular, end squarish, one long (10 µm), narrow (2 µm) cusp on each side of all lateral and marginal teeth.

Habitat. On fine green algal layer on mud just below mangroves, at midtidal levels.

Remarks. Smith (1992) recorded *Cassidula doliolum* from Queensland and the Northern Territory, a known range which is not modified here.

Cassidula doliolum is similar in colour to *C. nucleus*, and both have strong spiral striae. *Cassidula nucleus* can be distinguished by its larger size (mean length 17 mm vs 11 mm for *C. doliolum*) and stronger parietal and columellar folds. *Cassidula doliolum* is similar in size to *C. sowerbyana* (mean shell length of both is 11 mm) but can be distinguished by being a narrower shell with a less rounded spire. The spiral grooves of *C. doliolum* are less numerous than in *C. sowerbyana* but are stronger. The parietal and columellar folds and outer lip tooth of *C. doliolum* are all weaker than in *C. sowerbyana*.

The lateral and marginal radular teeth of *C. doliolum* differ from those of the three other species figured here in that they have a long (10 µm), narrow (2 µm) cusp on each side; these are lacking in the other species.

Cassidula sowerbyana (Pfeiffer, 1853)
Plate 2, Figs 11-12.

Auricula sowerbyana Pfeiffer, 1853: 125.

Cassidula sowerbyana (Pfeiffer) - Brazier 1877: 130.

Cassidula (*Cassidula*) *sowerbyana* (Pfeiffer) - Smith 1992: 213.

Location of types. 3 syntypes, BMNH 196982.

Table 5. Measurements of shells of *Cassidula doliolum*.

	Length	Width	Aperture	W/L	A/L
Adults only (n = 17) (AMS)					
Mean	11.5	6.2	6.1	0.54	0.53
1 S.D.	0.4	0.5	0.3	0.04	0.03
Range	10.9-12.0	5.3-6.8	5.6-6.7	0.47-0.60	0.47-0.58

Table 6. Measurements of shells of *Cassidula sowerbyana*.

	Length	Width	Aperture	W/L	A/L
Elizabeth Creek Station, Qld. (AMS)					
Mean (n=20)	11.4	6.2	5.9	0.54	0.51
1 S.D.	0.4	0.2	0.3	0.02	0.03
Range	10.5- 12.2	6.0-6.7	5.3-6.5	0.51-0.58	0.46-0.57

Type locality. Moreton Bay, Queensland.

Distribution. Broome, Western Australia to Sinclair Bay, Queensland.

Material examined. *Western Australia:* Broome (4 lots AMS); Lagrange Bay (AMS). **QLD:** Howick Group, No. 1 (AMS); Four Mile Beach, Port Douglas (AMS); Low Isles, near Port Douglas (AMS); Cardwell (AMS); Palm I. (AMS); Bowen (2 lots AMS); Sinclair Bay (AMS).

Description. *Shell.* Shell small for genus, to 12 mm, spire medium, triangular on upper surface but lower portion rounded, grading into body whorl. Protoconch minute, paucispiral, two whorls, forms slight bulb at top of spire, surface smooth. Suture very fine, straight, indistinct. Teleoconch of up to seven rapidly expanding whorls, base of spire whorls much larger than upper surface. Sculpture subdued, dominated by spiral striae, about eight on penultimate whorl, 35 on body whorl which extend to anterior tip of shell. Striae crossed by very fine axial growth lines. Aperture long, narrow, widest at bottom. Columella slightly callused with slight posterior parietal fold one third down length followed by strong, narrow anterior parietal fold two thirds down aperture, points into aperture, columellar fold near base of aperture, points upwards. Outer lip thickened with narrow outer lip swelling, broader at lower surface, slight swelling on lip just below upper margin of aperture, strong broad, pointed outer lip tooth followed by broader plate which forms lower two thirds of outer lip; margin of outer lip swelling slightly irregular. Lower margin of aperture rounded, thickened. Background colour of shell light gray but variable. Protoconch orangeish, spire yellowish gray spiral bands on upper whorl alternating with darker brownish bands on lower whorl, body whorl light gray with two indistinct broad bands of darker gray, may also have darker axial bands. Outer surfaces of aperture glossy white, interior dark glossy brown.

Radula. Not known.

Remarks. Smith (1992) recorded this species from northern Western Australia and Queensland. There are few museum records of *C. sowerbyana*, and the range is not extended here. *Cassidula sowerbyana* has not been recorded from the Northern Territory, but probably does occur there in areas of suitable habitat.

Cassidula sowerbyana is similar in size to *C. doliolum* (mean shell length of both is 11 mm) but can be distinguished by being a broader shell with a more rounded spire. The spiral grooves are more numerous than in *C. doliolum* but are much weaker. The parietal and columellar folds of *C. sowerbyana* are stronger than on *C. doliolum* and there are three on the columella of *C. sowerbyana* compared to two on *C. doliolum*.

Subfamily Ellobiinae
H. and A. Adams (in Pfeiffer), 1854
Genus *Ellobium* Röding, 1798

Type species. *Bulla auris-Judae* Linnaeus, 1758: 728, by subsequent designation.

Description. Derived genus; gizzard a stout, thick-walled chamber; narrow tubular lumen; posterior digestive diverticulum lost; spherical posterior caecum retained at apex of stomach; reproductive system specialized; glandular tract in two long channels, spermoviduct with second long glandular tube running parallel to it but joined at both ends; function unknown; penis complex, with six closely spaced coils; considerable internal shell resorption; foot simple undivided disk; tendency for reduction of central tooth of radula; obsolescence of denticles on marginals and laterals (Morton 1955a).

Shell large to very large, up to 100 mm long as adults, heavy. Protoconch minute, usually worn off, upper shell may be decollate. Spire low to medium height, generally triangular in outline with whorls rapidly increasing in diameter; upper surface of whorl may be much smaller than lower surface. Suture narrow, thin, may be slightly channeled. Shell surface generally smooth with low pustules. Whorls rounded or flattened, shoulder indistinct to medium strength. Varices present in some species. Aperture elongate, mouth heavily callused, narrow with two parietal folds, glossy white. Tropical Indo-Pacific. Common in many mangrove areas.

Note: *Ellobium* (*Auriculodes*) *album* (Gassies, 1865) was listed by Smith (1992: 214) but is considered to be *Microtralia alba* and belongs in the subfamily Pedipedinae (Martins 1992).

Ellobium aurisjudae (Linnaeus, 1758)

Plate 1, Fig. 5 and Plate 3, Figs 1-2

Bulla auris-Judae Linnaeus, 1758: 728.

Dautzenberg and Fischer (1905) provide an extensive synonymy of this species which is not repeated here. Only subsequent Australian references are listed below.

Ellobium aurisjudae (Linnaeus) - Hedley 1916: 215; 1918: 281; - Allan 1940: 198, figured; 1950: 363, pl. 27, fig. 10; - Rippingale and McMichael 1961: 155, pl. 21, fig. 23; - Coleman 1975: 18, sp. 24; - Short and Potter 1987: 120, pl. 59, f. 4.

Ellobium (*Ellobium*) *aurisjudae* (Linnaeus); - Smith 1992: 214.

Location of types and type locality. Unknown (Smith 1992).

Distribution. Indo-West Pacific: Northern Australia from Onslow, Western Australia to Moreton Bay, Queensland.

Material examined. *Western Australia.* Onslow area (AMS); Dampier (WAM); Nicol Bay (AMS); Cape Lambert (WAM); Port Hedland (AMS); Roebuck Plains (AMS); Broome (AMS); Vansittart Bay (AMS; WAM); Buccaneer Archipelago (AMS); SE Wood I., E of Cockatoo I. (WAM); Monja Stn., Walcott Inlet (AMS); Prince Regent River (WAM); Careening Bay, Kimberley (15°06'S; 125°00'E) (WAM); Coronation I., Kimberley (15°02'S; 124°55'E)(WAM); Hunter River, Kimberley (15°02'S; 125°25'E) (WAM); Port Warrender, Admiralty Gulf (10 lots WAM); 6 km S of Pickering Point, Admiralty Gulf (WAM). *Northern Territory, Australia.* Condor Point, Melville I. (AMS); Andranango Creek, Melville I. (AMS); Port Essington (QM); Darwin area (QM): Cox Peninsula (2 lots WAM); West side Darwin Harbour (WAM); Smith Point (WAM); Port Darwin (2 lots AMS); Race course Creek (AMS); Tee Point (AMS); Francis Bay (AMS); Shoal Bay, NE of Darwin (2 lots AMS); Ludmilla Creek (12°24'S; 130°49'E) (AMS); Tree Point, SE of Darwin (14°01'S; 129°36'E) (AMS); Buffalo Ck. (WAM; AMS); Channel I. (WAM); Rapid Creek (2 lots WAM; 3 lots NTM); Gunn Point, east of Darwin (WAM; NTM); South Alligator River (WAM); Yirrkala Mission, Arnhem Land (AMS); Goomadeer River (11°52'S; 133°48'E) (3 AMS); Nunbalgarri Creek (11°58'S; 134°02'E) (AMS); Bat I. (12°06'S; 134°11'E) (AMS); Djigagila Creek (12°09'S; 134°49'E) (2 lots AMS); Dorbilla Creek (12°11'S; 134°53'E) (AMS); Woolen R. (12°25'S; 135°23'E) (AMS); Buckingham R. (12°31'S; 135°43'E) (AMS); Habgood River (12°37'S; 135°51'E) (2 lots AMS); Liverpool R. (AMS); Maningrida, near Boucat Bay (AMS); Elcho I. (AMS). *Queensland, Australia:* Torres Str.: (AMS); Saibai Village, Saibai I., Torres Str. (3 lots AMS; 3 lots QM); Thursday I. (2 lots AMS); Moa (or Banks) I., Torres Str. (AMS); Murray I. (AMS); N Qld (AMS); Port Stewart, Cape York Penin. (AMS); Starcke R. (AMS); Lizard I. (AMS); Ninian Bay, S of Cape Melville (AMS); Cooktown (AMS); Annan R. (AMS); Trinity Bay (AMS); Machan's Beach, N of Cairns (AMS); Cairns (AMS); Dunk I. (AMS; QM); Cardwell (AMS; 4 lots QM); Hinchinbrook I. (2 lots AMS); Cardwell, N of Ingham (AMS); Townsville (AMS; WAM); Mooney's Bridge, Ross Creek, Townsville (AMS); Mouth of Ross R., Townsville (AMS); Bowen (AMS); Sinclair Bay, Edgecumbe Bay (AMS); Proserpine R. at Wilson (AMS); Wilson Beach (AMS); Proserpine (2 lots AMS); Keppel Sands, near Yeppoon (2 lots AMS); 32 km S of Yeppoon (AMS); Seaforth, Mackay (AMS; WAM); Mackay (AMS; QM); Ross Ck., Yeppoon (AMS); Keppel Bay (AMS); Gladstone (QM); Cape Capricorn, Curtis I., near Gladstone (AMS); Port Curtis (2 lots AMS); Facing I., Port Curtis (AMS); Sarina Beach (21°24'S; 149°10'E) (AMS); Moreton Bay (AMS). *Papua New Guinea:* Marike Village, S coast (WAM); Kiwai I., Fly River (WAM); Labu, (AMS); Labu, mouth of Markham R., near Lae (AMS). *Solomon Is.:* (QM). *Singapore:* (4 lots WAM). *Malaysia:* E coast (AMS); Kuantan, E Malaysia (3°48'N; 103°20'E) (2 lots AMS); Muar, W Malaysia (2°02'N; 102°24'E) (2 AMS); 146°57'E) (2 lots AMS); Pulau, Asmara Batu, Ferringhi, Penang (AMS); Sarawak (AMS); Mahakam R., E. Borneo (AMS); Victoria, SE side Labuan I., Sabah (AMS). *Thailand:* Kan Klong, Tamrhu, Chanburi Prov. (AMS). *The Philippines:* (AMS); Batangas Bay, Batangas Prov., Luzon

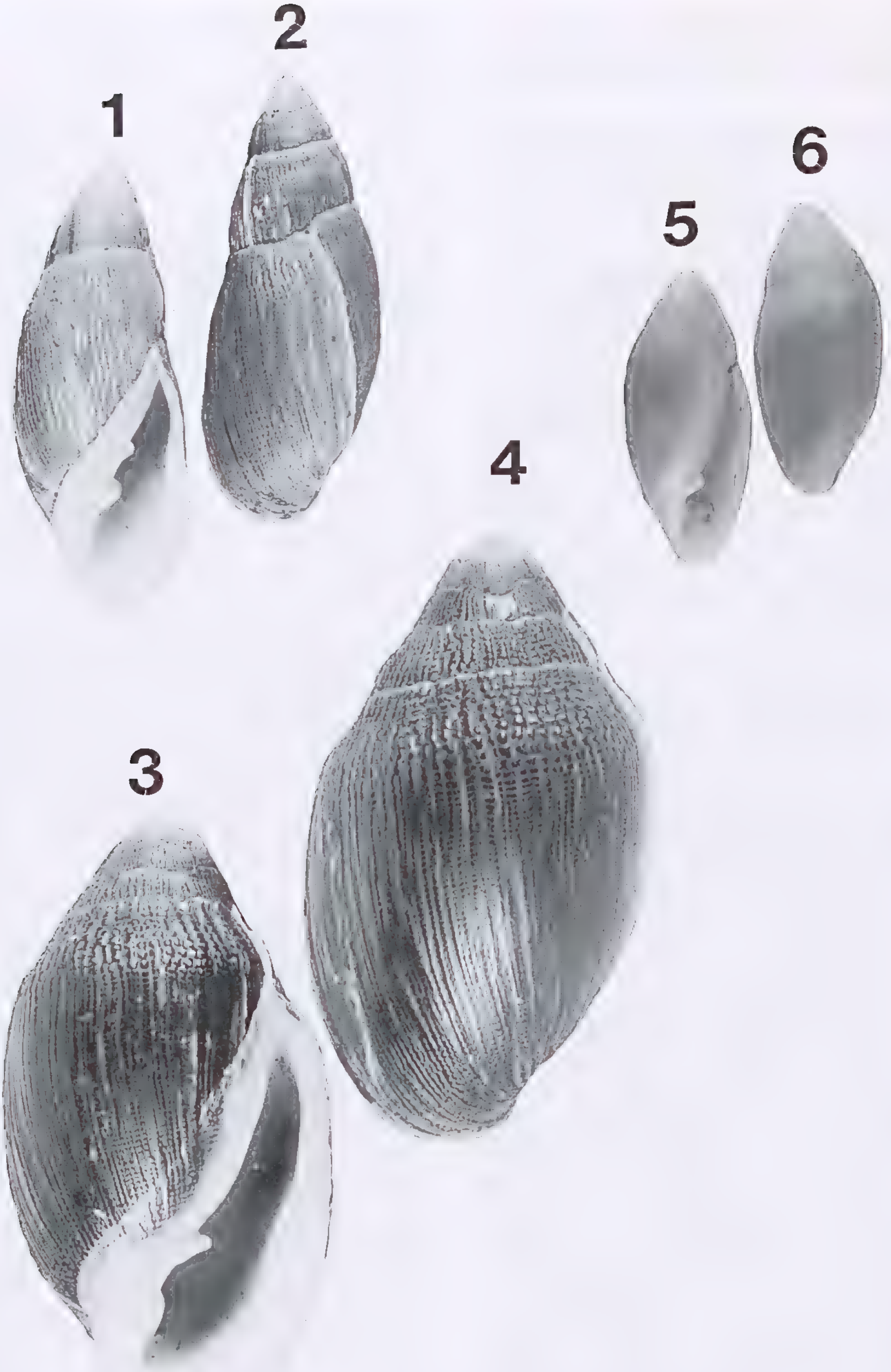

Plate 3. Shells of *Ellobium*. **1-2.** *E. aurisjudae* (Linnaeus, 1758). Port Warrender, Admiralty Gulf, W.A. WAM 1358-78. **3-4.** *E. aurismidae* (Linnaeus, 1767). Sarawak, Borneo, Malaysia. WAM 114- 94. **5-6.** *E. semisculptum* H. and A. Adams, 1854.

I. (AMS); Igbon Village, near Panay (11°13'S; 123°10'E) (AMS); Cebucao Beach, Panglan I. (9°38'N; 123°49'E) (2 lots AMS); Agho I., near Panay I. (11°14'N; 123°12'E) (2 AMS); Mobini, Batangas Bay (WAM).

Description. *Shell.* Shell of medium size for genus, up to 60 mm high, narrow, solid. Protoconch very small, but shells decollate. Upper whorls enlarge rapidly but rate of increase much smaller in penultimate whorl. Up to seven teleoconch whorls. Suture narrow, distinct, nearly straight, whitish in colour. Entire shell surface sculptured by fine axial striae crossed by fine spiral striae to form continuous surface of low nodules, up to 60 vertical nodules on body whorl. Strong breaks may occur in shell where growth interrupted, but no varices. Inner lip slightly flared out, heavily thickened, surface a flat plate up to 7 mm wide on lower surface. Columella moderately broad, callused, lower surface smooth, anterior end of shell rounded. Aperture elongate, lower end rounded, upper substantially narrowed. Outer lip tooth indistinct, about one third down aperture. Inner surface of aperture with two strong, narrow parietal folds near middle and columellar fold near lower end. Shell uniform off-white but completely covered by brown periostracum. White shell shows through in areas where periostracum has worn off.

Radula. Rachidian tooth small, wishbone shaped, 30 µm high, 10 µm wide, with upper end and lower flares capped and strengthened. Lateral teeth grading into marginals with no clear distinction. About 30 teeth per half row, innermost teeth large (40 µm high, 25 µm wide), projecting above basal plate, squarish with central area slightly wider than upper margin, teeth becoming narrower (15 µm) towards margin.

Habitat. Upper intertidal. Buried deep in rotten mangrove logs where there is considerable moisture. Also found buried in mud or mud among rocks at the landward sides of mangroves where the sediment surface is protected by a thick layer of leaves and moisture is retained.

Remarks. Smith (1992) recorded *Ellobium aurisjudae* from northern Western Australia to Queensland, which accords with the present data.

Ellobium chinense (Pfeiffer, 1855) is a very similar species, but is smaller (to 35 mm versus up to 55 mm) and has a more rounded shell. *Ellobium aurismidae* is easily separated from *E. aurisjudae* by its larger size (100 mm vs. 60 mm), broader shape, and the presence of a varix on the body whorl.

Morton (1955a) based his conclusions on the evolutionary relationships of the genus *Ellobium* on *E. aurisjudae*, and provided considerable information on the species.

Ellobium aurismidae (Linnaeus, 1767)

Plate 1, Fig. 6 and Plate 3, Figs 3-4

Bulla Auris-Midae Linnaeus, 1767: 1186.

Dautzenberg and Fischer (1905) provide an extensive early synonymy of this species which is not repeated here. Only subsequent Australian references are listed below.

Ellobium aurismidae (Linnaeus) - Allan 1940: 198, figured; 1950: 363, pl. 27, fig. 10; - Rippingale and McMichael 1961: 154-155, pl. 21, fig. 22 (possibly north Queensland); - Coleman 1975: 19, sp. 25; - Short and Potter 1987: 120, pl. 59, fig. 8.

Ellobium (*Ellobium*) *aurismidae* (Linnaeus) - Smith 1992: 214.

Location of types. Presumed lost (Smith 1992).

Type locality. Unknown (Smith 1992).

Distribution. Widespread in the Indo-West Pacific: Thailand and the Philippines to Indonesia.

Table 7. Measurements of shells of *Ellobium aurisjudae.*

	Length	Width	Aperture	W/L	A/L
Buffalo Creek, Darwin					
Mean (n=20)(WAM)	46.1	18.6	23.6	0.41	0.51
S.D.	3.8	1.6	1.9	0.02	0.04
Range	38.1-54.0	14.3-21.2	18.7-26.5	0.36-0.46	0.45-0.59
West side, Darwin Harbour					
Mean (n= 45) (WAM)	41.4	16.9	24.8	0.40	0.48
S.D.	4.8	1.4	2.8	0.02	0.03
Range	28.1-51.4	13.8-20.1	17.4-24.5	0.37-0.44	0.42-0.53

Material examined. *Papua New Guinea:* (AMS). *Indonesia:* (AMS); Aru Is. (2 lots AMS); Radja Ampat (5°32'S; 132°18'E) (AMS); Kaimana (AMS); Kaipoeri, Koeroedoi I, Geelvink Bay (2 AMS); Sailolof, Salawati I. (1°16'N; 130°46'E) (AMS); Japen I. (AMS); Ambon (AMS). *Singapore:* (AMS). *Malaysia:* Tasek Dayang, Bunting, Pulau Langkawi, W. Malaysia (6°12'N; Melaka, W. Malaysia (2°12'N; 102°15'E) (AMS); Sarawak (AMS); Gam R., Borneo? (AMS). *Thailand:* Welu R., Chanthaburi (AMS). *The Philippines:* Manila? (2 lots AMS). *Uncertain records:* WA (AMS); ?Derby area (WAM); NT: Darwin (AMS); QLD: Cardwell (QM).

Description. *Shell.* Shell very large, up to 100 mm high, heavy, moderate spire. Tip of spire decollate, protoconch missing. Up to nine rapidly enlarging teleoconch whorls forming a broad triangle on spire. Suture narrow, slightly adpressed, distinct, slightly irregular, light coloured. Entire shell surface sculptured with narrow axial growth lines crossed by fine spiral striae to form numerous rows of fine nodules. Nodules distinct on upper whorls; 11 rows of low nodules on penultimate whorl of 100 mm specimen extend onto lower surface of suture, making it irregular. About 15 strong rows of nodules on body whorl but these become progressively indistinct below shoulder and taper out, strengthen again on lower body whorl and are strong at anterior tip of shell. Outer lip strongly thickened and slightly flared out, forming broad plate up to 10 mm wide at lower margin. Strong varix 180° before aperture. Smaller varix may be present one whorl above aperture. Back of shell rounded in smaller specimens, flatter in large specimens. Aperture long, narrow, slightly curved, lower margin rounded, upper forms distinct notch. Columella flattened over shell surface. Strong narrow posterior parietal fold just inside aperture, strong, anterior parietal fold one-third up from lower surface of aperture, and smaller columellar fold just above anterior of shell. Shells off-white covered by light brown to chocolate brown periostracum; aperture, outer lip, columella semiglossy off-white. Sutures and top of shell off-white. Lower surface may be strongly eroded by acid on mud surface.

Radula. Rachidian tooth small, wishbone shaped, 45 μm high, 20 μm wide, with upper end and lower flares capped and strengthened. Lateral teeth grade into marginals with no clear distinction. About 30-40 teeth per half row, innermost teeth large (55 μm high, 45 μm wide), project above basal plate, squarish with central area slightly wider than upper margin, teeth become narrower (20 μm) towards margin.

Habitat. Not seen in the field, but probably similar to that of *E. polita* which occurs on the surface of wet mud at the back of mangroves. Restricted in habitat to only a few areas.

Remarks. *Ellobium aurismidae* has been recorded from northern Australia by Allan (1940; 1950), Coleman (1975), Short and Potter (1987), and Smith (1992). Rippingale and McMichael (1961) figured the species and stated that it possibly occurs in northern Queensland. All of these works, except Smith (1992) are popular publications and no specific records of *E. aurismidae* are listed. It is likely that the above authors were simply basing their information on the first records (Allan 1940).

The collections examined have only five records of this species from northern Australia. Two lots are in the Australian Museum - one from Western Australia and a second from Dar-

Table 8. Measurements of shells of *Ellobium aurismidae.*

	Length	Width	Aperture	W/L	A/L
Aru I., AMS C.35435	93.6	46.7	50.7	0.50	0.54
	82.1	42.8	42.3	0.52	0.52
	85.1	47.2	47.5	0.55	0.56
	78.0	42.4	42.0	0.54	0.54
	79.9	39.8	42.5	0.50	0.53
Geelvink Bay, W Irian Jaya, AMS C.90424					
	97.8	53.2	51.2	0.54	0.52
	99.8	49.9	53.4	0.50	0.54
	90.4	47.6	51.7	0.53	0.57
	95.1	51.8	54.0	0.54	0.57
	87.2	47.3	48.6	0.54	0.56
	88.4	51.4	52.4	0.58	0.59
	57.3	28.6	29.5	0.50	0.51

win, Northern Territory; neither shell has a collection date, so whether they were obtained either before or after Allan (1940) cannot be determined. Both are dead shells which may have come from elsewhere. The Western Australian specimens have no collection data and the collector is not known. The Darwin specimen is from the Garrard Collection, which is known to have incorrect locality data incorporated in it. The malacology department at the Australian Museum has not received a specimen from northern Australia for identification (Loch, pers. comm.). The Queensland Museum also has two lots of *E. aurismidae* with unconfirmed data, one from Cardwell and one mixed lot labeled as "Cardwell and Singapore". The Western Australian Museum has a single lot from ?Derby area. In a paper on mangroves of northern Queensland McNae (1967) records *E. aurismidae* as being present in the Townsville area, but no voucher material is available.

While the presence of *E. aurismidae* in northern Australia would not be surprising, it cannot be confirmed.

Ellobium polita (Metcalfe, 1851) from Hong Kong is smaller than *E. aurismidae* (up to 80 mm vs 100 mm) and more rounded. Juveniles of *E. aurismidae* are in fact very similar to large specimens of *E. polita*, but the varix on the shell of *E. polita* is only about 150° from the aperture instead of 180°. Numerous fine spiral striae occur on the shell surface of *E. polita* but they are not nodulose as in *E. aurismidae*.

Ellobium aurisjudae is easily separated from *E. aurismidae* by its smaller size (60 mm vs 100 mm), narrower shape, and the lack of a varix on the body whorl.

Ellobium semisculptum
H. and A. Adams, 1854 (1855)

Plate 3, Figs 5-6.

Ellobium semisculptum H. and A. Adams, 1854 (1855): 9.

Ellobium (*Auriculodes*) *semisculptum* H. and A. Adams - Smith 1992: 214.

Location of types. Presumed lost (Smith 1992).

Type locality. Unknown (Smith 1992).

Distribution. Indo-Pacific; North West Cape, Western Australia to Hervey Bay, Queensland.

Material examined. *Western Australia:* Lighthouse Beach, North West Cape (AMS). *Northern Territory, Australia:* Port Darwin (AMS); Port Keats (AMS). *Queensland, Australia:* N end Yam I., Torres Str. (AMS); Warrior I., Torres Str. (AMS); Murray I., Torres Str. (3 lots AMS); Banks I. (Moa I.), Torres Str. (AMS); Annan R. (AMS); Sinclair Bay (AMS); Thirsty Sound (AMS); Bundaberg (2 lots AMS); Gatokers Bay, Hervey Bay (AMS); Eli Ck., Hervey Bay (AMS); Lord Howe I. (AMS). *Papua New Guinea:* North Coast (AMS). *Solomon Is:* Bougainville Str. (AMS). *New Caledonia:* (8 lots AMS); New Hanover (AMS). *Fiji:* Kiva, (AMS); Suva (AMS); Kautaru (AMS); Kardavu (AMS). *Sri Lanka:* (AMS).

Description. *Shell.* Shell small for genus, less than 20 mm long, light, spire high, pointed, but usually decollate at tip. Suture thin, distinct, nearly straight. Up to eight teleoconch whorls. Shell surface smooth except for microscopic nodules two thirds of spire whorls. Approximately 15 rows of nodules on upper surface of body whorl continue below shoulder but are indistinct. No varices on body whorl. Outer lip not flared, slightly thickened; inner surface smooth. Aperture long, narrow, constricted at upper end, rounded at lower margin. Columella slightly callused, one strong, narrow parietal fold well down columella followed by lower but broader columellar fold near lower margin of aperture. Anterior tip of shell rounded. Columella and aperture off-white. Exterior of shell also off-white but covered by light brown periostracum.

Radula. Not known.

Remarks. Smith (1992) recorded *Ellobium semisculptum* from the Northern Territory and Queensland, but the range is here extended into northern Western Australia.

Table 9. Measurements of shells of *Ellobium semisculptum*.

	Length	Width	Aperture	W/L	A/L
Banks I. (Moa I.) Torres Str. (AMS C.31163)					
Mean (n=25)	15.1	7.6	9.3	0.49	0.60
1 S.D.	3.0	1.7	1.5	0.04	0.07
Range	8.5-21.2	4.3-13.1	5.5-11.6	0.44-0.62	0.45-0.71

Ellobium semisculptum can be easily confused with juveniles of *E. aurisjudae*. Juveniles of *E. aurisjudae* can be distinguished by having a broader shell, the spire of which enlarges much more rapidly. The aperture begins higher on the body whorl on *E. aurisjudae* below which the shell narrows more rapidly. The folds on the columella are lower on *E. semisculptum* than on *E. aurisjudae*. Low nodules on the lower whorls of the spire of *E. semisculptum* extend only two thirds of the way down the whorl in contrast to covering the complete whorl on *E. aurisjudae*.

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COPIDOGNATHINAE (HALACARIDAE, ACARI) FROM NORTHERN AUSTRALIA; DESCRIPTION OF FOUR NEW SPECIES.

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ABSTRACT

Four new species of the halacarid subfamily Copidognathinae (*Copidognathus foveatellus* n. sp., *C. euryalus* n. sp., *C. elaboratus* n. sp., and *Acarothrix longiunguis* n. sp.) are described from Darwin Harbour. *Copidognathus euryalus* and *C. elaboratus* belong to the *bairdi* group, a group of closely related species recorded from warm water areas around the globe. *Acarothrix* is supposed to be an exclusively brackish water genus.

KEYWORDS: Halacarid mites, *Copidognathus, Acarothrix*, new taxa, tidal area, northern Australia.

INTRODUCTION

The halacarid mite subfamily Copido-gnathinae holds about one-third of all halacarids described. The majority of the species belongs to *Copidognathus* Trouessart, a genus that is world-wide in distribution, and common from tropical to arctic regions (Viets 1956). The other genera, *Acarothrix* Bartsch, *Phacacarus* Bartsch, *Werthella* Lohmann, and *Copidognathides* Bartsch, include only few species and, according to present records, have a more restricted geographical range. *Acarothrix* is present only in brackish waters in tropical and subtropical regions (Bartsch 1990a); *Phacacarus* is known from western Australia (Bartsch 1992b); *Werthella* from the southern hemisphere (Bartsch 1986b), and *Copidognathides* from the North and South Atlantic Ocean (Bartsch 1990a).

Halacarids taken near Darwin, north Australia, and sent to me for examination, belong to the genera *Copidognathus* and *Acarothrix*.

AREA INVESTIGATED, MATERIAL AND METHODS

The mites described were collected in July 1993 by C. Erséus, K.A. Coates and B. Healy, participants in the Sixth International Marine Biological Workshop 'The Marine Flora and Fauna of Darwin, Northern Territory, Australia'.

Darwin Harbour, in the Northern Territory, lies within the tropical area (Knox 1963). The average daily maximum temperature is generally above 30 °C (Castles 1989), the surface sea water temperature in summer and winter is above 25 °C (Sverdrup *et al.* 1970; Ingmanson and Wallace 1989), and surface salinity is 35 ppt (Sverdrup *et al.* 1970; Brown *et al.* 1989). The lower intertidal zone comprises vast mudflats. At about mean sea level, mangroves are the dominant intertidal habitat. The edges of tidal creeks are composed of layers of fine muds to coarse sand. Outcrops of rocks are scattered between the subtidal and intertidal area (Hanley, pers. comm.). The habitats in tidal areas are exposed to large amplitudes in respect to temperature and salinity, with raised salinity values during insolation, but considerable runoff of freshwater during tropical summer rain. The tide is semi-diurnal; the tidal range exceeds 5 m, and is 8 m on springs (Ingmanson and Wallace 1989; Hanley, pers. comm.). Coastal waters are derived from the Pacific Ocean as well as from the South China Sea and western coast of Australia (Sverdrup et al. 1970; Tchernia 1980; Brown et al. 1989).

In: Hanley, J. R., Caswell, G., Megirian, D. and Larson, H.K. (eds). *Proceedings of the Six International Marine Biological Workshop. The marine flora and fauna of Darwin Harbour, Northern Territory, Australia.* Museums and Art Galleries of the Northern Territory and the Australian Marine Sciences Association: Darwin, Australia, 1997: 231–243.

The mites were cleared in lactic acid and mounted in glycerine jelly. Drawings were prepared using a camera lucida. Holotypes and paratypes are deposited in the Museum and Art Gallery of the Northern Territory, Darwin (NTM); other material in the author's halacarid collection.

Abbreviations used in the descriptions: AD, anterior dorsal plate; AE, anterior epimeral plate; ds, dorsal setae on idiosoma; ds-1, first pair of dorsal setae; GA, genitoanal plate; GO, genital opening; OC, ocular plate(s); P, palp; P-2, second palpal segment; pas, parambulacral setae; PD, posterior dorsal plate; PE, posterior epimeral plate; pgs, perigenital setae; sgs, subgenital setae; vs, ventral setae on idiosoma. Legs numbered I to IV, leg segments 1 to 6, I-6, tarsus on leg I.

SYSTEMATICS

Copidognathus foveatellus n. sp.
(Fig. 1A-K)

Type material. HOLOTYPE male (NTM A74), north of Darwin, Ludmilla Creek, edge of tidal creek, coarse sand, 12 July 1993, coll. C. Erséus.

Description. *Male.* Idiosoma 291 µm long, 176 µm wide. Dorsal plates evenly sculptured with 6-9 µm wide foveae, and each fovea with about 20 canaliculi (Fig. 1D). AD 100 µm long, 94 µm wide; anterior margin rounded, posterior margin rather truncate. First pair of gland pores in anterior portion of AD. OC 87 µm long, 38 µm wide; posterior corner somewhat pointed (Fig. 1A). Gland pore inserted anteriorly within lateral corner. Corneae lacking. PD 192 µm long, 125 µm wide. Raised costae lacking. Gland pores inconspicuous. All dorsal setae small; setae ds-1 inserted on AD, between pair of gland pores; ds-2 in anterior corner of OC, ds-3 to ds-5 on PD, namely near anterior margin (ds-3), posterior to level of insertion of leg III (ds-4) and posterior to that of leg IV (ds-5). Setae ds-6 on anal plate.

Ventral plates marginally with foveae and canaliculi; median portion of AE with canaliculi arranged in groups, median portion of GA with small pores. AE 97 µm long, 155 µm wide, with large and triangular medial epimeral processes (Fig. 1B), three pairs of ventral setae and one pair of epimeral pores, latter constricted by about eight tooth-like protrusions. Posterior margin of AE truncate. PE each with one dorsal and three ventral setae. GA 140 µm long, 122 µm wide. Anterior margin truncate. GO small, 30 µm long, 25 µm wide; sclerites anteriorly covered by membrane. Distance from anterior margin of GO to that of GA equalling twice the length of GO. Genital sclerites with four pairs of subgenital setae. Perigenital setae arranged widely around GO.

Gnathosoma 85 µm long. Basis of gnathosoma with large foveae and numerous canaliculi. Tectum triangular. Rostrum shorter than base of gnathosoma. Maxillary setae as illustrated (Fig. 1C). P-2 and P-4 rather similar in length. P-2 with one dorsal seta. P-4 with three setae in basal whorl.

Leg I distinctly wider than other legs. Telofemur I with ventromedial and ventrolateral lamellae. Lateral flank of telofemora I and II and tibiae I and II each with canaliculi (Fig. 1I); both lateral and medial flank of I-3 reticulate (Fig. 1E). Leg chaetotaxy, from trochanter to tibia: leg I, 1, 2, 5, 3, 7; leg II, 1, 2, 4, 3, 7; leg III, 1, 2, 2, 3, 5; leg IV, 0, 2, 2, 3, 5. Ventromedial bristles on I-5 short and delicately bipectinate. Bipectinate bristles on tibia II longer (Fig. 1F). Both III-5 and IV-5 with bipectinate ventromedial bristle (Fig. 1G, H). Tarsus I with three long dorsal setae and seta-like dorsolateral solenidion. Interval between two basalmost dorsal setae less than that between second and distalmost dorsal seta; latter seta inserted adjacent to solenidion (Fig. 1J). Basalmost of three ventral setae long, extending beyond insertion of paired setae. Tip of tarsus I with pair of single parambulacral setae. Tarsus II with three dorsal setae, one long, bluntly ending dorsolateral solenidion, pair of single parambulacral setae, but no ventral setae (Fig. 1K). Distance between basalmost dorsal seta and following seta less than that between latter seta and distalmost seta. Tarsi III and IV long and slender. Tarsus III with four dorsal setae, basalmost one being shorter and ending bluntly. Tarsus IV with three dorsal setae.

Claws on tarsus I shorter than on posterior tarsi. All claws with accessory process, tarsi II to IV with few rather long tines. Median claw present on all tarsi.

Female. Not seen.

Remarks. The most obvious characters in *C. foveatellus* are the evenly foveate dorsal plates, pierced by numerous canaliculi, and the

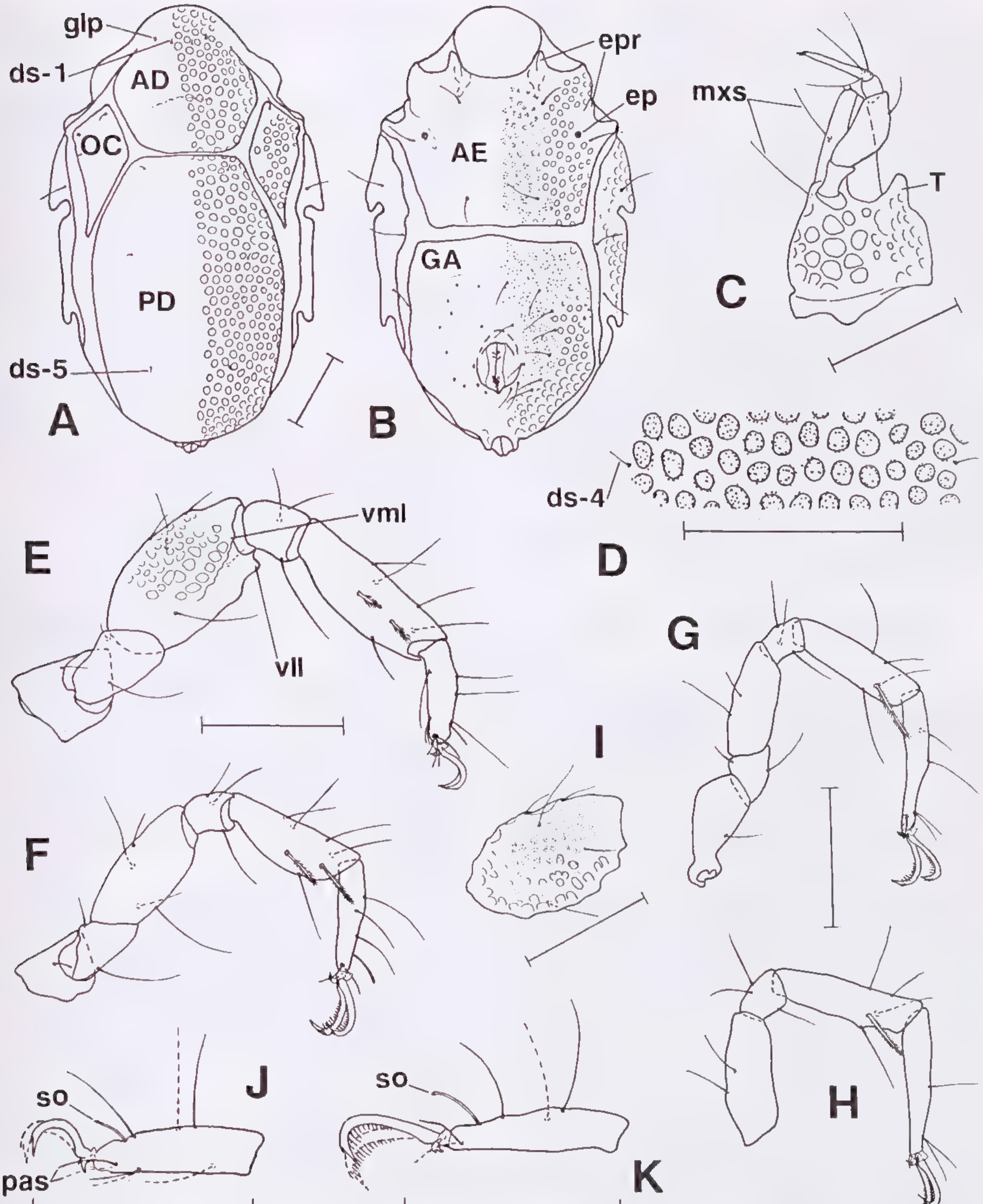

Fig. 1. *Copidognathus foveatellus* n. sp., male. **A**, Idiosoma, dorsal aspect; **B**, idiosoma, ventral aspect; **C**, gnathosoma, lateral aspect; **D**, portion of PD between ds-4; **E**, leg I, medial aspect; **F**, leg II, medial aspect; **G**, leg III, medial aspect; **H**, basifemur - tarsus IV, medial aspect; **I**, telofemur I, lateral aspect; **J**, tarsus I, lateral aspect (medial setae and claw in broken line); **K**, tarsus II, lateral aspect (medial setae and claw in broken line). (Abbreviations: **AD**, anterior dorsal plate; **AE**, anterior epimeral plate; **ds-1**, first pair of dorsal setae; **ds-4**, fourth pair of dorsal setae; **ds-5**, fifth pair of dorsal setae; **ep**, epimeral pore; **epr**, epimeral process; **GA**, genitoanal plate; **glp**, gland pore; **mxs**, maxillary setae; **OC**, ocular plate; **pas**, parambulacral setae; **PD**, posterior dorsal plate; **so**, solenidion; **T**, tectum; **vll**, ventrolateral lamella; **vml**, ventromedial lamella). Scale bar = 50 µm.

chaetotaxy of genua I and II, with three instead of the generally four setae. Uniformly foveate sculpturing of the dorsal plates is described from *Copidognathus caudani* (Trouessart), *C. cribosoma* (Police), *C. isopunctatus* Bartsch, *C. matthewsi* Newell and *C. rhodostigma rondus* Bartsch. These species have four setae on genua I and II. Species with reduced number of setae on genua I and II are *C. occultans* Bartsch, *C. cerberoideus* Bartsch, *C. consobrinus* Bartsch and *C. inusitatus* Bartsch. *Copidognathus occultans* has three setae on genua I and II, *C. cerberoideus* and *C. consobrinus* both have the number of setae reduced to two. These three species are arenicolous, they are small, about 200-250 µm long, and the dorsal plates lack foveae. They inhabit shallow water sandy deposits in the Hong Kong area (Bartsch 1991b). *Copidognathus inusitatus,* a deep-sea species (Bartsch 1989), has three setae on genua I and II but five on genua IV.

Copidognathus euryalus n. sp.
(Fig. 2A-L)

Type material. HOLOTYPE male (NTM A75), north of Darwin, Ludmilla Creek, edge of tidal creek, coarse sand, 12 July 1993, coll. C. Erséus.

Other material. One female (NTM A76) and one male (author's collection), Rapid Creek, Nightcliff, fine silty sediment in rockpool, 9 July 1993, coll. K.A. Coates.

Description. *Male.* Idiosoma 335-340 µm long, 223-230 µm wide, holotype 340 µm long and 230 µm wide. Dorsal plates with porose areolae, demarcated and raised above reticulate remainder of plates. Reticulum formed by epicuticular 'droplets' fused to small ridges (Fig. 2I). Rosette pores within porose areolae each with ostium, rather deep alveolus, but without surrounding canaliculi. AD (of holotype) 109 µm long, 96 µm wide; anterior margin lightly protruding, remainder of AD hexagonal. Four porose areolae present, one oblong in anterior portion of plate with almost 20 rosette pores, pair of crescent areolae in middle of plate, each with about 18 pores and ending with gland pore, and transverse posterior areola with six pores (Fig. 2A). OC 92 µm long, 60 µm wide; porose areolae present medial and lateral to two large corneae, and in posterior portion of OC; former with about 10 pores each, latter with four to eight (seven in holotype) rosette pores. Large gland pore adjacent to corneae; eye pigment and gland beneath corneae. PD 212 µm long, 170 µm wide. Each half of plate with two longitudinal costae which anteriorly are more or less contiguous. Porose areolae anteriorly two, posteriorly three rosette pores wide, and rarely one pore wide. Both pairs of gland pores in posterior PD. Glands beneath plate oblong, about 40 µm long.

Ventral plates with canaliculi, 6-25 arranged within polygons (Fig. 2J), and porose areolae with rosette pores (Fig. 2B). Each rosette pore with central alveolus surrounded by 5-10 canaliculi. AE 107 µm long, 201 µm wide, rather uniformly covered with polygons; small porose areolae present only marginally. PE with distinct marginal and ventral porose areolae. GA 172 µm long, 145 µm wide, anterior rectangular portion of GA with canaliculi arranged within polygons; lateral areas of GA with distinctly raised, garland-like porose areolae. GO 50 µm long, 35 µm wide. Genital sclerites with four pairs of sgs. The 15-18 pairs of perigenital setae arranged in wide ring around GO. Spermatopositor large; extending beyond GO somewhat more than length of GO.

Gnathosoma 94 µm long. Integument of base of gnathosoma pierced by canaliculi (Fig. 2L). Rostrum shorter than base of gnathosoma and extending almost to end of P-2. Palps short, P-2 with dorsal seta. P-4, shorter than P-2, with three setae in basal whorl.

Leg I slightly stouter than posterior legs and shorter than legs III and IV. Telofemur I 2.3 times longer than high; ventral lamellae lacking. Telofemora II - IV 2.3, 3.0 and 3.5 times longer than high. Leg chaetotaxy, from trochanter to tarsus (pas included): leg I, 1, 2, 5, 4, 7, 11; leg II, 1, 2, 5, 4, 7, 8; leg III, 1, 2, 2, 3, 5, 6; leg IV, 0, 2, 2, 4, 5, 6. Tibia I with three ventral bristles; one short and slightly pectinate, two tapering and smooth (Fig. 2D). Tibia II with two ventromedial, bipectinate bristles; ventrolateral bristle slender and smooth (Fig. 2E). Ventromedial bristle on tibia III blunt and bipectinate; ventrolateral bristle slender and smooth (Fig. 2F), and both bristles on tibia IV slender and smooth (Fig. 2G). Ventral seta on tarsus I long, pair of ventral setae half as long (cf. Fig. 2H). Solenidion on lateral membrane of claw fossa seta-like and 10 µm long. Solenidion on tarsus II 13 µm long and inserted on lateral membrane of claw fossa

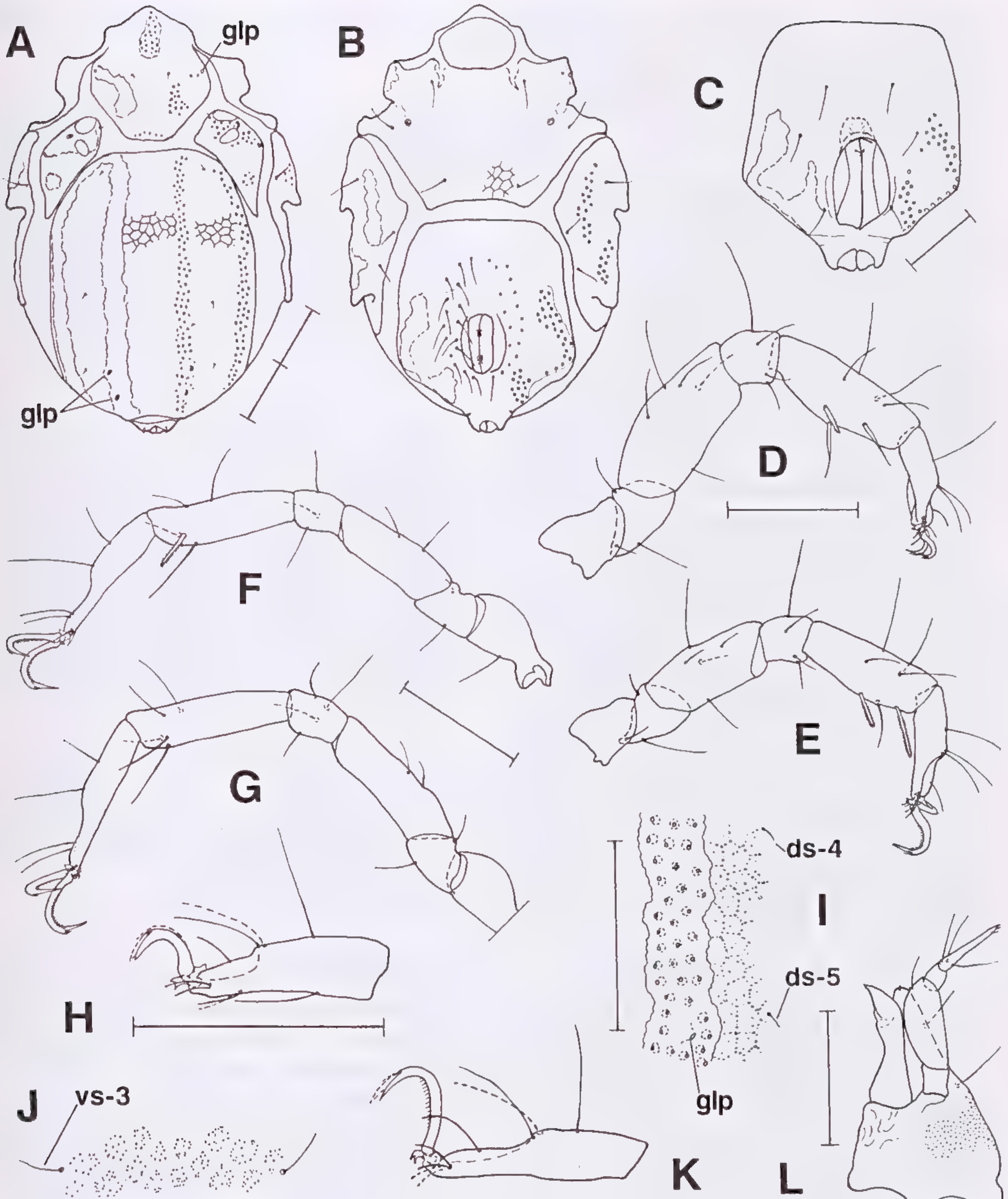

Fig. 2. *Copidognathus euryalus* n. sp. **A**, Idiosoma, dorsal aspect, male (right side shows ostia from rosette pores, left side outline of raised areolae); **B**, idiosoma, ventral aspect, male; **C**, genitoanal plate, female; **D**, leg I, medial aspect, male; **E**, leg II, medial aspect, male; **F**, leg III, medial aspect, male; **G**, leg IV, medial aspect, male; **H**, tarsus I, lateral aspect, female (medial setae and claw in broken line); **I**, portion of PD with left ds-4, ds-5 and gland pore, male (alveoli in deeper integumental layers in broken lines); **J**, portion of AE between third pair of ventral setae, male; **K**, tarsus II, lateral aspect, female (medial setae and claw in broken line); **L**, gnathosoma, lateral aspect, male. (Abbreviations: **ds-4**, fourth dorsal seta; **ds-5**, fifth dorsal seta; **glp**, gland pore; **vs-3**, third pair of ventral setae). Scale bar = 50 μm.

(cf. Fig. 2K). Tarsus II longer than tarsus I. Tarsi III and IV both with four dorsal setae. Parambulacral setae doubled on tarsi I and II, single on tarsi III and IV. Lateral pas on tarsus III spur-like, medial pas seta-like; both pas on tarsus IV spur-like.

Claws on tarsus I distinctly shorter than those on posterior tarsi. Claws with accessory process, and claws on tarsi II - IV with pecten. Tines of pecten delicate (Fig. 2K).

Female. Idiosoma 347 µm long, 245 µm wide. In dorsal aspect similar to male. GA 165 µm long, 141 µm wide, in outline similar to that of male; with garland-like porose areolae on either side of GO. GO 60 µm long, 37 µm wide. Three pairs of pgs arranged as figured (Fig. 2C). Distance from anterior margin of GA to that of GO somewhat more than length of GO. Ovipositor slightly surpassing the GO.

Remarks. *Copidognathus euryalus* belongs to the *bairdi* group (Bartsch 1984a), a natural group characterized by the combination of: PD with two or four longitudinal costae with rosette pores and two pairs of prominent gland pores; ovipositor only slightly extending beyond GO; spermatopositor large, extending beyond GO for length of GO; genu IV with four setae. Representatives of the *bairdi* group are spread in tropical and warm-temperate waters all around the globe.

The *bairdi* group *sensu lato* in turn can be subdivided. The sub-groups, their characters and records from the eastern Indian and western Pacific ocean are:

bairdi group *sensu stricto*

Characters. Palps surpass the rostrum; both ventral bristles on tibia IV slender; tarsi III and IV each with four dorsal setae.

Records. Copidognathus sidellus Bartsch, in sediment from 10 m depth, Cebu, Philippines (Bartsch 1985b); *C. sideus* Bartsch, from thalli of halophytes and red algae, Bay of Bengal (Chatterjee and Sarma 1993); *C. euryalus*, from tidal area, northern Australia.

ornatus group

Characters. Dorsal plates with large porose areolae; telofemora I - IV with ventral lamellae.

Records. Copidognathus acanthoscelus Bartsch, from tidal sediment, southern China (Bartsch 1992c); *C. umbonatus*, in sandy deposits in upper tidal area, southern China (Bartsch 1992c).

spinula group

Characters. AD prolonged into frontal spine; telofemur I with enlarged ventral lamella and tibia I with remarkably stout ventral bristle.

Records. Copidognathus spinula (Trouessart), Vietnam (Trouessart 1899). *C. gitae* Chatterjee, on littoral algae covered with sediment, Bay of Bengal (Chatterjee 1991b). *C. monacanthus* Bartsch, in sediment from lower tidal beach, southern China (Bartsch 1992c).

temaeus group

Characters. Palps short, hardly surpassing the rostrum; P-2 with spinular lamella; telofemur I often with spinular ventral lamella; tibia I with two blunt spurs with spinose tips.

Records. Copidognathus temaeus Bartsch, from tidal reef, Society Islands (Bartsch 1992d); *C. malaysius* Bartsch, from tidal reef area, eastern coast of peninsular Malaysia (Bartsch 1993a); *C. elaboratus* n. sp., from sand between coral heads, northern Australia.

gibberipes group

Characters. Palps rather short, though distinctly surpassing the rostrum; telofemur I often with spinular ventral lamella; tibia I with two blunt spurs with spinose tips.

Records. No Indo-West Pacific record.

Copidognathus euryalus is most similar to *C. sidellus* and *C. sideus*. *Copidognathus sideus*, with a length of 260 µm, is smaller than the other species, the ventral setae on both genu and tibia I are remarkably long, and the telofemora III and IV are only slightly more than twice as long as high. Differences between *C. euryalus* and *C. sidellus* are: pair of porose areolae on AD crescent-shaped in *C. euryalus* but almost circular in *C. sidellus*; AD of *C. euryalus* 1.1 longer than wide, that of *C. sidellus* 1.3 longer than wide; PD wider in *C. euryalus* than in *C. sidellus*; pair of anterior gland pores on PD on a level with ds-5 in *C. euryalus*, but distinctly posterior to ds-5 in *C. sidellus*; porose areolae on GA of *C. euryalus* garland-like, porose areola of *C. sidellus* smaller and elongate; pecten on claws of *C. euryalus* with numerous, delicate tines, of *C. sidellus* with few but strong tines.

Copidognathus elaboratus n. sp.
(Fig. 3A-N)

Type material. HOLOTYPE female (NTM A77), off Darwin Harbour, Cox Peninsula, 2 km east of Charles Point, sand patch with heterogeneous sand, gravel and shells between coral heads, about 1 m below low water mark, 12 July 1993, coll. G. Edgar and C. Erséus.

Description. *Female.* Idiosoma 325 µm long, 222 µm wide. Dorsal plates with raised, porose areolae with rosette pores, each rosette pore with small ostium at surface of plate, and about six canaliculi in deeper integumental layers. Areas of plates outside porose areolae reticulate, with each of the larger polygons subdivided (Fig. 3C). AD longer than wide, 100 µm long, 72 µm wide; anteriorly with short and rounded frontal process. AD with three elongate raised areolae, viz. median anterior and pair of posterior ones. Pores from glands almost 5 µm in diameter, placed lateral to anterior edge of pair of porose areolae. OC large, 92 µm long, 59 µm wide; with two large corneae. Raised and elongate porose areola medial to corneae, another areola lateral to corneae, and crescent raised areola in distolateral portion of OC (Fig. 3A). PD 182 µm long, 137 µm wide. Anterior PD rounded; with pair of longitudinal raised costae. Both pairs of gland pores placed distinctly posterior to level with insertion of leg IV. Setae ds-1 on AD, anterior to edge of pair of porose areolae; ds-2 in anteromedial margin of OC; ds-3 to ds-5 on PD immediately lateral to costae, ds-3 near anterior edge of raised costae, ds-4 slightly anterior to level with insertion of leg IV, ds-5 immediately posterior to gland pore; ds-6 on anal cone.

Major parts of ventral plates coarsely porose; pores often arranged within polygons, and generally each pore within polygon with two to four canaliculi in deeper integumental layers (Fig. 3D). Areas within epimera and on either side of posterior GO slightly raised; porosity more distinct than in remainder of plate. Porosity almost lacking within T-shaped area on AE and around ventral setae (Fig. 3B). AE 105 µm long, 200 µm wide; with three pairs of setae and pair of epimeral pores. GA 155 µm long, 110 µm wide; GO 65 µm long, 45 µm wide; distance from anterior margin of GO to that of GA slightly less than length of GO. Three pairs of pgs inserted as figured. Subgenital setae in anterior third of genital sclerites. Ovipositor slightly extending beyond GO.

Gnathosoma 122 µm long. Integument of gnathosomal base punctate (Fig. 3H). Rostrum almost as long as gnathosomal base. Tectum truncate. Palps slender, not extending beyond tip of rostrum. P-2 with lamellar ventral spine and rather delicate dorsal seta (Fig. 3J). P-3 short, only 4 µm long; P-4 18 µm long, with three setae in basal third.

Leg I longer than following legs (Figs 3K-N). Telofemur I as long as tibia I. Telofemora on other legs slightly shorter than tibiae. Telofemora I - IV 2.1, 1.9, 1.9, and 2.2 times longer than high. Ventral lamella on telofemur I extremely short, hardly set off from segment and perceptible only at lateral aspect. Telofemora II - IV without ventral lamellae. Tibiae distally with small articular membranes. Number of setae, from trochanter to tarsus (pas included): leg I, 1, 2, 5, 4, 7, 11; leg II, 1, 2, 5, 4, 7, 7; leg III, 1, 2, 2, 3, 5, 6; leg IV, 0, 2, 2, 4, 5, 5-6. Tibia I ventrally with slender bristle and two short spines, latter having blunt and serrate tip (Fig. 3I). Tibia II ventrally with slender and smooth bristle and two bipectinate bristles; tibia III with slender and smooth bristle and very short, bipectinate spine; tibia IV with both ventral bristles being slender and smooth. Tarsus I distinctly longer than tarsus II, and higher than tarsi II - IV. Tarsus I with three ventral and three dorsal setae, dorsolateral 13 µm long solenidion, and pair of doubled pas (Fig. 3E); dorsomedial membrane of claw fossa present but very small; dorsolateral membrane of claw fossa with solenidion and canicular famulus. Tarsus II with three dorsal setae and seta-like, 17 µm long dorsolateral solenidion (Fig. 3F). Tarsus III with seta-like medial pas and spine-like lateral pas; both pas on tarsus IV spine-like. Right tarsus IV with three dorsal setae (Fig. 3N), left tarsus IV with four setae (Fig. 3G).

Claws on tarsus I smaller than on posterior tarsi. All claws with long accessory process but without pecten.

Male. Not seen.

Remarks. *Copidognathus elaboratus* is a member of the *bairdi* group *s.l.*, and closely related to *C. temaeus* and *C. malaysius*. The longitudinal costae on PD are two pores wide in *C. elaboratus*, generally three pores wide in *C. malaysius*, and one pore wide in *C. temaeus*. The ventral lamella on telofemur I is smaller in *C. elaboratus* than in *C. malaysius* and *C. temaeus*. *Copidognathus elaboratus* and *C. malaysius* have a porose areola in the posterior

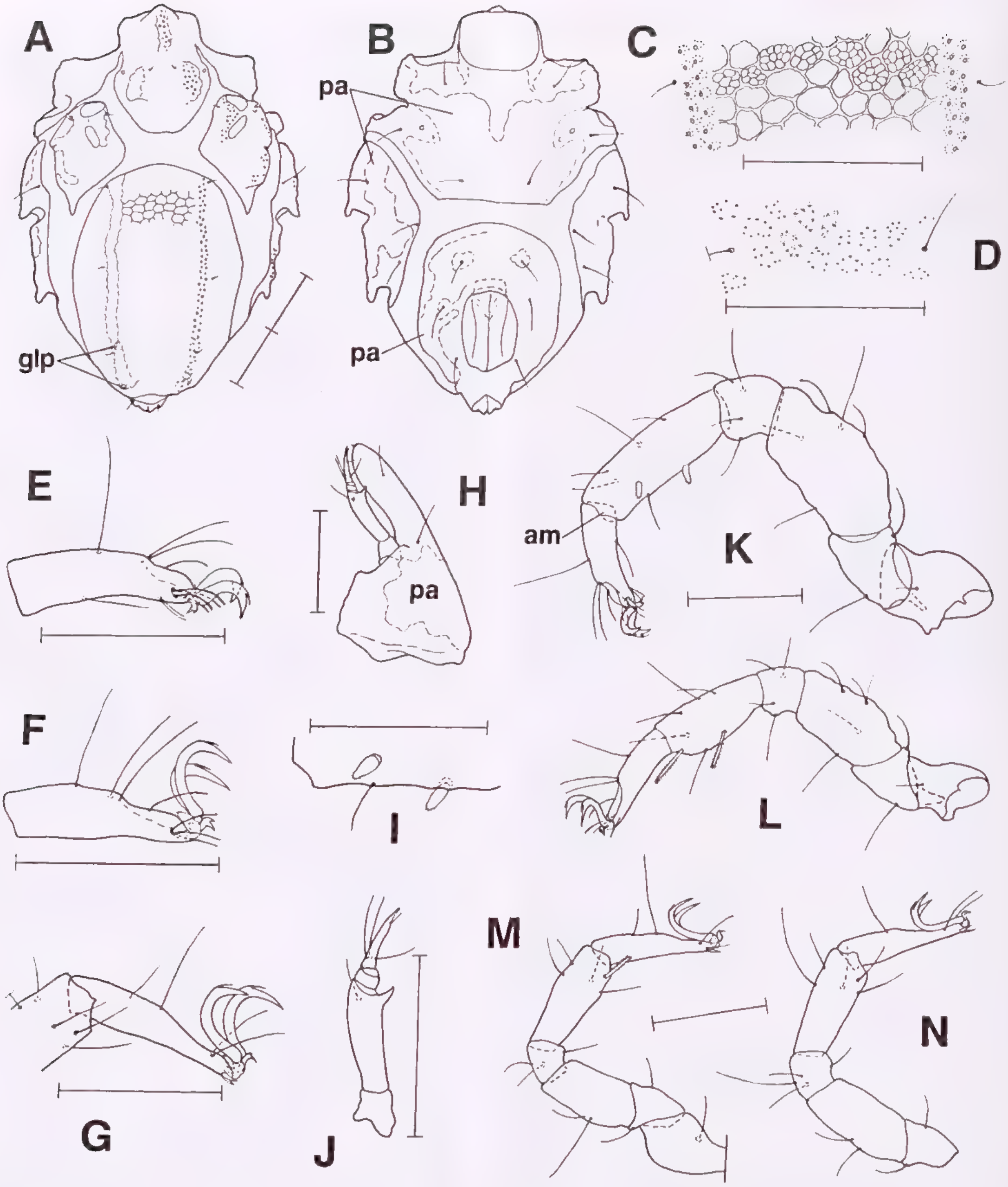

Fig. 3. *Copidognathus elaboratus* n. sp., female. **A**, Idiosoma, dorsal aspect (right side shows ostia from rosette pores, left side outline of raised areolae); **B**, idiosoma, ventral aspect (with outline of porose areolae); **C**, portion of PD between ds-4 (rosette pores with canaliculi; subdivision of polygons illustrated within a transverse row); **D**, portion of posterior AE with pores arranged in polygons (three of the polygons show the canaliculi of the deeper integumental layers); **E**, tarsus I, lateral aspect; **F**, tarsus II, lateral aspect; **G**, posterior tibia and tarsus IV, lateral aspect; **H**, gnathosoma, lateral aspect; **I**, ventral portion of tibia I, medial aspect; **J**, palp, lateral aspect; **K**, leg I, medial aspect; **L**, leg II, medial aspect; **M**, leg III, medial aspect; **N**, basifemur - tarsus IV, medial aspect. (Abbreviations: **am**, articular membrane; **glp**, gland pore; **pa**, porose areola). Scale bar = 50 µm.

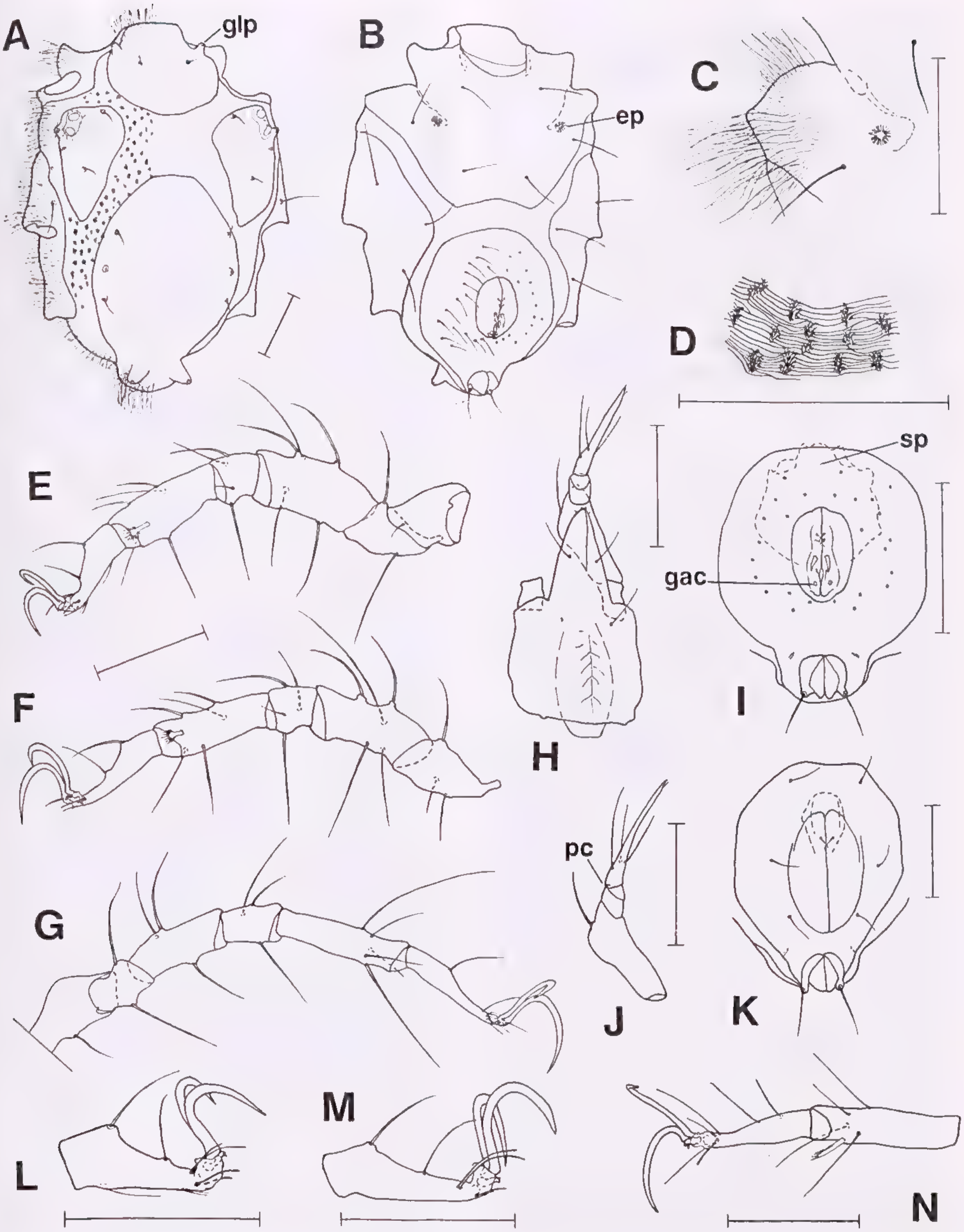

Fig. 4. *Acarothrix longiunguis* n. sp. **A**, idiosoma, dorsal aspect, male; B, idiosoma, ventral aspect, male; **C**, portion of AE with epimeral pore, male; **D**, portion of membraneous integument between AD, OC and PD, male; **E**, leg I, medial aspect, male; **F**, leg II, medial aspect, male; **G**, leg IV, medial aspect, male; **H**, gnathosoma, ventral aspect, female; **I**, genitoanal plate, male; **J**, palp, male; **K**, genitoanal plate, female; **L**, tarsus I, lateral aspect, female; **M**, tarsus II, lateral aspect, female; **N**, tibia and tarsus III, ventral aspect, male. (Abbreviations: **ep**, epimeral pore; **gac**, genital acetabulum; **glp**, gland pore; **pc**, pore canaliculus; **sp**, spermatopositor). Scale bar = 50 μm.

OC, whereas the OC of *C. temaeus* lack that areola; the claws of *C. temaeus* are distinctly stouter than those of the other two species.

Acarothrix longiunguis n. sp.

(Fig. 4A-N)

Type material. HOLOTYPE male (NTM A78), Sadgroves Creek, mangrove area near Darwin, outer bank of creek, soft mud with fibres, brownish at surface, dark grey below, intertidal, 11 July 1993, coll. B. Healy.

PARATYPES male (NTM A79) and female (NTM A80), collecting data as above. One female and one male, author's collection, collecting data as above.

Description. *Male.* Idiosoma and legs covered with debris trapped between dense epicuticular filaments. Idiosoma 278-286 µm long, holotype 278 µm long, 198 µm wide. Membraneous integument with spinose tubercles ending with filaments (Fig. 4D). AD 70 µm long, 87 µm wide. Anterior margin truncate, posterior margin rounded (Fig. 4A). Pair of ds-1 inserted on 3 µm long tubercles. OC 85 µm long, 52 µm wide; with two corneae on slightly raised area, surrounded by delicate filaments. Gland pore placed on small cone lateral to posterior cornea, pore canaliculus posterior to gland pore. Dark eye pigment beneath the two corneae. Setae ds-2 and ds-3 on OC, on 3-4 µm long tubercles. PD 162 µm long, 112 µm wide. Short ds-4 and ds-5 on small tubercles anterior and posterior to pair of cone-like gland pores. Cones with posterior - most gland pore large, 15 µm long. Setae ds-6 in ventral position, placed on anal plate adjacent to anal sclerites. Posterior idiosoma beset with long filaments.

Outline of ventral plates obscured by dense villosity; ventral filaments shorter than those marginally and dorsally. Membraneous integument without spinose tubercles. AE 92 µm long, 174 µm wide. Epimeral pores slightly enlarged, about 10 µm in diameter and with about 12 tines (Fig. 4C). Posterior margin of AE slightly concave. PE with one dorsal and three ventral setae. GA 124 µm long, 102 µm wide. GO rather large, 50 µm long, 32 µm wide; with 12-16 perigenital setae on either side of GO (Fig. 4B). Genital sclerites with pair of small genital acetabula (Fig. 4I) and four pairs of sgs: two anterior pairs seta-like, next pair spur-like and distal pair seta-like.

Gnathosoma 89 µm long, 55 µm wide. Rostrum triangular, about as long as length of gnathosomal base. Two pairs of maxillary setae and two pairs of rostral setae as illustrated (cf. Fig. 4H). Rostral sulcus extending beyond apical-most pair of maxillary setae. P-2 with apical half swollen and with strong seta (Fig. 4J). P-3 with neither seta nor spine. P-4 with dorsal transverse pore canaliculus, and three setae inserted within basal fourth of segment.

Legs slender. Leg segments and their setae covered with filaments. Filaments on tibiae and tarsi less conspicuous than those on more basal segments. Telofemur I 2.3 times longer than high and slightly longer than tibia I; II-3 as long as II-5; III-3 and IV-3 distinctly shorter than tibiae. Number of setae on legs, from trochanter to tibia: leg I, 1, 2, 5, 4, 6; leg II, 1, 3, 5, 4, 6; leg III, 1, 2, 3, 3, 5; leg IV, 1, 2, 3, 3, 5. Dorsal setae on basifemora and telofemora rather wide and inserted on small tubercles. Tibiae I and II each with four dorsal and two ventral setae; ventrolateral one long, ventromedial seta short, fan-shaped and bipectinate (Fig. 4E, F). Tibiae III and IV each with three dorsal setae; ventrolateral seta of tibia III long and slender, ventromedial one short and fan-shaped (Fig. 4N); tibiae IV with both ventral setae being slender (Fig. 4G). Tarsi I and II (cf. Fig 4L, M) with three dorsal setae and seta-like solenidion, latter inserted immediately adjacent to apicalmost (dorsolateral) seta. Tarsus II with both solenidion and apicalmost setae ending bluntly preceding (dorsomedial) seta slender. Tarsi I - IV with 3, 3, 4, 3 dorsal setae. Ventrally, tarsus I with one long seta and pair of small setae; apically with pair of pas. Tarsi II - IV lack ventral setae. Tarsus II with long and short parambulacral setae on either side of apex of tarsus; tarsus III with blunt ended seta and one slender seta; both pas on tarsus IV long and slender.

Claws very long and slender, without any filaments. Claws almost smooth, delicate dent of accessory process generally obscured. Median claw small, bipectinate.

Female. Idiosoma 279-294 µm long. In dorsal aspect similar to male. GA 130 µm long, 105 µm wide, not as wide as genitoanal plate of male. GO 68 µm long, 37 µm wide. Interval between anterior margin of GO and that of GA same as 0.4 the length of GO (Fig. 4K).

Remarks. This is the second representative of the genus *Acarothrix. Acarothrix longiunguis* is distinguished from *A. palustris* Bartsch on the basis of the prominently raised cones in posterior PD and the very long and slender claws.

Both species have been found in soft mud in mangrove areas, *A. palustris* in southern China (Bartsch 1990a) and *A. longiunguis* in tropical Australia. *Acarothrix palustris* is known to withstand an extreme salinity range, from almost fresh, when in the rainy season the saltmarsh area is covered by fresh water, to hypersaline, when the sun is drying up these upper tidal pools (Bartsch 1990a). *Acarothrix longiunguis* may withstand a similar range in salinity.

Acarothrix longiunguis is characterized by: 1, dense coating with debris trapped within the filaments; 2, raised cones with aperture of gland pores at the apex; and 3, long claws.

A coating with delicate filaments is present in numerous halacarids (Alberti *et al.* 1981; Bartsch 1984c, 1986b, 1987, 1990c). The coating in species inhabiting the upper tidal fringe is thought to reduce water loss during low water periods. Remarkably long filaments are recorded from several deep-sea species, from *Agaue* Lohmann, *Werthella* Lohmann and *Werthelloides* Bartsch (Bartsch 1986b, 1987). The filaments are present in moulting instars, and, when they hatch, debris is quickly trapped within the filaments (Bartsch 1987). Elaborate cuticular surface structures such as spiny horns, pattern with microscales, feathery hairs and areolae or rows of cuticular spinelets are commonly found in marine arthropods (Barnard 1973; Meyer-Rochow 1980; Thistle 1982; Vaupel Klein 1982; Lincoln and Boxshall 1983; Hulsemann and Fleminger 1990). Some of these structures are thought to prevent settlement of other organisms on the cuticle (Meyer-Rochow 1980). Spiny horns and feathery hairs easily trap debris, and that sediment-covering may protect their bearers from selective predators in providing incorrect chemical, tactile and size cues (Thistle 1982). In *Acarothrix longiunguis*, an inhabitant of tidal flats with soft mud, the coating seems to be similar to that of deep-sea halacarid species. Three possible functions of the dense coating with debris-trapping filaments are: A, it is a camouflage that protects the mites, inhabiting muddy areas without a macroporous substrate that gives shelter, from predators with tactile and chemical prey discrimination; B, it reduces or moderates the impact of rapidly altering or extreme amplitudes in salinity or temperature; and C, it prevents the mites from sinking into deeper anoxic layers within an ooze-like sediment.

The second remarkable feature of *Acarothrix* are the gland cones, each cone with an aperture near its apex. Similarly raised cones are reported from representatives of the *Agaue corollata* group (Bartsch 1987, 1990c). The cones raise the aperture of the gland above the coating with cuticular filaments.

Long and slender claws, as present in *A. longiunguis*, are commonly found in deep-sea halacarids (Newell 1967; Bartsch 1978, 1982, 1989), and also in exclusively subterranean living freshwater halacarids (Walter 1931). Elongation of claws are thought to correlate with life in a soft sediment.

DISCUSSION

The four species collected in the Darwin area, Northern Australia, are new to science, though related to species recorded from adjacent areas. Northern Australia lies within the tropical zone. Prevailing surface water currents in the winter are from the east, in the summer from south west and north west (Tchernia 1980). Faunal exchange should be possible with the western Pacific as well as with the western coast of Australia, the China Sea and the eastern Indian Ocean.

The halacarid fauna from adjacent areas is incompletely known, and only scattered records on Copidognathinae are known from the eastern Indian Ocean (Chatterjee 1991a-c, 1992; Sarma and Chatterjee 1991; Chatterjee and Sarma 1993), Mekong Delta (Trouessart 1896, 1899), Malaysia (Bartsch 1993a), Hong Kong area (Bartsch 1990a-b, 1991a-b, 1992a, c), the Philippines (Bartsch 1984b, 1985a-b, 1986a), and Western Australia (Bartsch 1992b, 1993b). *Acarothrix longiunguis* is related to *A. palustris*, a species recorded from the Hong Kong area (Bartsch 1990a). More species are expected to be found in mangrove areas in the Indo-West Pacific region. *Copidognathus euryalus* and *C. elaboratus* both belong to the *bairdi* group (*s.l.*). A species closely related to *C. elaboratus* is mentioned from peninsular Malaysia (Bartsch 1993a); another very similar though distinct species was found on the western coast of Australia amongst shallow water corals (*Pocillopora* sp.) (unpublished record). *Copidognathus euryalus*, from northern Australia, and *C. sidellus*, from the Philippines, both belong to the same natural group. According to present records, corresponding shallow water habitats separated by large coastlines or seaways have similar copidognathine faunas, with sibling though distinct species.

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THE CIROLANIDAE (CRUSTACEA: ISOPODA) OF DARWIN HARBOUR, NORTHERN TERRITORY, WITH ADDITIONAL RECORDS FROM NORTHERN AUSTRALIA AND PAPUA NEW GUINEA.

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ABSTRACT

Twenty four cirolanid isopod species are reported from Darwin Harbour, raising the total number known from this area to 26. Sixteen of these are recorded for the first time from the Northern Territory. Additional range extensions, including localities in north-western Australia, Queensland and Papua New Guinea, are also incorporated. A lectotype is designated for *Aatolana schioedtei* (Miers, 1884). Three new species are described, two in the genus *Natatolana* and one in the genus *Plakolana*. Six species of *Cirolana* not previously recorded from Australia, and possibly undescribed, are also documented but not described. The only species in the genus *Limicolana* is reported for the first time as a scavenger. The diversity and biogeography of the species occurring in Darwin Harbour, and the importance of cirolanid isopods as members of the scavenging guild are briefly discussed. Keys to all of the species recorded are provided.

KEYWORDS: Isopoda, Cirolanidae, taxonomy, biogeography, ecology, scavenging, necrophagous, tropical, Australia, Papua New Guinea.

INTRODUCTION

The Cirolanidae of Australia were thoroughly reviewed by Bruce (1986). Subsequently an additional six species have been described from northern and south-eastern Australia (Bruce 1991, 1992, 1994; Bruce and Humphreys 1993). Bruce (1986: 7) noted that on the eastern Australian coast, cirolanid species diversity markedly increases in the tropics. However, until the present study only 13 (*Aatolana schioedtei*, *Cirolana capricornica*, *C. improceros*, *C. mekista*, *C. stenoura*, *Excirolana orientalis*, *Limicolana dinjerra*, *Natatolana angula*, *N. variguberna*, *Neocirolana excisa*, *Neocirolana hermitensis*, *Neocirolana salebra* and *Pseudolana menartae*) of the 108 species known from Australia had been recorded from the Northern Territory (Bruce 1986, 1994), the most northern part of mainland Australia after Cape York Peninsula. Hanley (1988) has commented that virtually nothing is known of diverse and important components of the Darwin Harbour crustacean fauna such as isopods. Only four species of cirolanid have been recorded from Darwin (*A. schioedtei*, *C. stenoura*, *N. angula* and *Neocirolana excisa*) (Bruce 1986, 1994).

The Sixth International Marine Biological Workshop held at Darwin Harbour during July, 1993, provided an opportunity to further assess the diversity of the cirolanid fauna of this area and gather material for taxonomic study.

MATERIALS AND METHODS

Specimens were collected using baited traps as outlined in Keable (1992, 1995). Habitats sampled included subtidal sediments and rock or coral reefs. Intertidal beaches, mangroves and rocky shores were also sampled but less intensively than the subtidal habitats. Sampling was carried out in areas ranging from off the coastal beaches near Nightcliff, north-east of

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the entrance to Darwin Harbour, to reaches south of Channel Island, approximately 20 km within the harbour. Sampling was most concentrated between West Point and Channel Island, however, samples were also collected in West Arm and in the vicinity of North and South Shell Islands, East Arm. Overall, 77 samples were collected; the bulk of this material has been deposited in the Australian Museum except as noted in the text. Based on an inspection of these samples, personal observations are included regarding the distribution of the taxa collected in Darwin Harbour. However, for the common species only voucher material is included in the material examined sections. A list of stations mentioned in the text is given in Appendix 1. The collections of the Northern Territory Museum of Arts and Sciences (NTM) and the Australian Museum (AM) were also examined for further material.

The description of the subtidal sedimentary habitats sampled in this study follows Michie (1988) who has summarised information on the sediments and sedimentary environments of Darwin Harbour. In this scheme, four sediment facies are recognised: terrigenous gravels; calcareous sands and gravels; terrigenous sands; muds and fine sands. The scour zone is formed in the main tidal channel and occupies the central area of the harbour (between approximately 10 and 30 m depth). This is dominated by gravel sediments, these are enclosed by terrigenous sands which are in turn enclosed by mud flats in the shallow subtidal embayments and upper reaches of the harbour. Within the harbour calcareous sand and gravel is largely restricted to Fannie Bay directly inside the eastern harbour entrance, and this sediment extends outside the harbour to the northeast.

Preliminary identifications of the species present were made using the keys of Bruce (1986) and Bruce (1993).

Restricted synonymies are given for all genera and species, and only the primary and the most recent taxonomic references are included.

In order to describe the new species, lateral views of the whole animal and dorsal views of the cephalon were illustrated using a dissecting microscope and drawing tube. Specimen lengths were measured, along the curvature of the body from the anterior of the rostral point to the median apex of the pleotelson, by tracing the outline of whole animal illustrations with a mapping scaler. Complete dissections were made of all appendages and mouthparts from the left hand side of the body unless these were damaged on this side. Dissected parts were temporarily mounted on microscope cavity slides in glycerine. These parts were illustrated using a compound microscope and drawing tube. Illustrations were subsequently traced with ink on drawing film to produce the published plates. Following illustration dissected parts were placed in microvials and returned to the same vials as the torso.

The description of new species follows the terminology used by Bruce (1986) and the conventions regarding orientation of appendages used by Bruce (1993). However, the recommendations of Oshel and Steele (1988), Watling (1989) and Wilson and Ponder (1992) regarding use of the terms spine and setae have been followed in order to avoid confusion regarding the homology of these structures. The term spine(s) is reserved for non-articulated cuticular extensions and the term seta(e) to delineate articulated extensions. Therefore, the term "robust seta(e)" used here is equivalent to the term spine as used by Bruce (1986, 1993) and the term "slender seta(e)" is equivalent to use of the word seta(e) without qualification. In this study setae are implied to lack setules unless qualified with an adjective such as pappose, plumose or penicillate. Use of these descriptive terms follows the definitions and illustrations of Watling (1989) and Wilson and Ponder (1992). The term setal row is used to replace the term lacinia mobilis, used by some authors to describe the setose lobe on the cirolanid mandible, as discussed by Brusca *et al.* (1995).

These descriptions have been generated from the taxonomic data base program DELTA (Dallwitz 1980; Watson *et al.* 1989; Dallwitz *et al.* 1993). Unless indicated otherwise, the following character states are implicit throughout the descriptions (but not the diagnoses) of the species of *Natatolana*. This device is used so that character states represented in most species of *Natatolana* are not constantly repeated, consequently shortening these descriptions.

Cephalon: cephalic ridges absent. *Frontal lamina*: sculpting absent. *Clypeus*: not sculpted. *Labrum*: without lamina projection. *Antennule*: short, not reaching pereonite 1; peduncle colinear; flagellum with aesthetascs present. *Antenna*: peduncular article 4 length subequal to article 3; flagellum without digitate processes on articles.

Mandible: molar with marginal robust setae present. *Maxillule*: endopod with three robust and pappose setae, lateral margin with a well developed lobe. *Maxilliped*: palp articles free, not fused.

Coxal plates: shallow, not as high as long; coxa 2 with anteroventral corner not produced into acute tooth.

Pleonites: five present, all equally visible. *Pleonite 1*: posterolateral margins not produced into distinct spiniform processes. *Pleonite 2*: dorsal and ventral posterolateral margins not formed into distinct spiniform processes, ventral posterolateral margin acute but not formed into a particularly long curved process. *Pleonite 3*: posterolateral margins produced; acute.

Pleotelson: broad, basal width larger than length; smooth, ornamentation and sculpting absent; posterolateral margins not conspicuously serrate.

Pereopods 1-3: propodus posterodistal angle with 1 robust seta opposing dactylus. *Pereopod 3*: ischium anterodistal angle produced subequal to that of pereopods 1-2. *Pereopods 4-6*: becoming progressively longer. *Pereopods 5-7*: propodus not short and robust on each pereopod or greatly elongate on pereopod 5 relative to pereopod 7. *Pereopod 7*: ischium length greater than width, anterior margin without robust setae. Merus, length greater than width. Merus, carpus and propodus anterior margins without robust or slender setae.

Pleopod 2 appendix masculina: width slender. *Pleopod 5*: with proximal lobe of medial margin strongly produced.

Uropods: peduncle medial margin strongly produced; exopod lanceolate.

The following abbreviations are used in the text and plates: AM - Australian Museum, Sydney; BMNH - The Natural History Museum, London; NTM - Northern Territory Museum of Arts and Sciences, Darwin; QM - Queensland Museum, Brisbane; USNM - National Museum of Natural History, Washington, D.C.; ZMUC - Zoologisk Museum, University of Copenhagen; x - times; CE - cephalon; A1 - antennule; A2 - antenna; CL - clypeal region; MD - mandible; MP - maxilliped; MX1 - maxillule; MX2 - maxilla; PN - pleon; P1-7 - pereopods 1-7; U - uropod; PL2 - pleopod 2; PT - pleotelson.

LIST OF SPECIES RECORDED FROM THE VICINITY OF DARWIN HARBOUR

Aatolana ?rapax
Aatolana schioedtei (Miers, 1884)
Cartetolana integra (Miers, 1884)
Cirolana capricornica Bruce, 1986
Cirolana improceros Bruce, 1986
Cirolana kendi Bruce, 1986
Cirolana mekista Bruce, 1986
Cirolana stenoura Bruce, 1986 (recorded from intertidal sandstone at Nightcliff, Darwin, by Bruce (1986))
Cirolana sp. 1
Cirolana sp. 2
Cirolana sp. 5
Cirolana sp. 6
Cirolana sp. 7
Cirolana sp. 8
Excirolana orientalis (Dana, 1853)
Limicolana dinjerra Bruce, 1986
Natatolana angula Bruce, 1986
Natatolana lowryi sp. nov.
Natatolana luticola (Holdich, Harrison & Bruce, 1981)
Natatolana taiti sp. nov.
Natatolana tenuistylis (Miers, 1884)
Natatolana thalme Bruce, 1986
Natatolana variguberna (Holdich, Harrison & Bruce, 1981)
Neocirolana excisa (Richardson, 1910) (recorded from sponge substrate, 11 m depth, at Channel Island, Darwin Harbour, by Bruce (1994))
Plakolana mandorah sp. nov.
Pseudolana menartae Bruce, 1986

SYSTEMATICS

Initial key to genera and species recorded from Darwin Harbour after Bruce (1986).

Separate keys follow for species of *Aatolana*, *Cirolana* and *Natatolana*.

1 a Clypeus freely projecting relative to the frontal lamina 2
  b Clypeus abutting frontal lamina in a similar plane, not projecting relative to it .. 3

2 a Rostrum subquadrate in dorsal view, fused to the frontal lamina. .... *Excirolana orientalis*
  b Rostrum forming a small point in dorsal view, not fused to the frontal lamina ....*Pseudolana menartae*

3 a Pleonite 3 with an acute posterolateral point and distinct ventrolateral incision visible in lateral view ....*Plakolana mandorah*

b Pleonite 3 with an acute or rounded posterolateral point, lateral margins meeting smoothly, no ventrolateral incision visible in lateral view. 4

4 a Pereopod 7 basis broad (width approximately half length), with a row of long plumose setae along the anterior margin (i.e. opposite margin to which dactylus folds toward) and posterodistal angle; pleonite 3 without a row of setae on lateral surface .... *Natatolana*

b Pereopod 7 basis broad or narrow (width much less than half length), plumose setae short, sparse or absent along the anterior margin and posterodistal angle; pleonite 3 with or without a row of setae on lateral surface 5

5 a Pleopods 3-4, endopods with plumose marginal setae 6

b Pleopods 3-4, endopods without plumose marginal setae .... *Limicolana dinjerra*

6 a Pleonite 3 posterolateral margins with a distinct row of setae on medial longitudinal carina .... *Aatolana*

b Pleonite 3 posterolateral margins without a distinct row of setae on lateral surface 7

7 a Mandible with molar forming a prominent blade-like process, incisor with anterior tooth smaller than or subequal to other teeth 8

b Mandible with molar small and not readily apparent, incisor with anterior tooth strongly produced into a curved process which is much larger than other teeth .... *Cartetolana integra*

8 a Uropod endopod lateral margin with a deep excision .... *Neocirolana excisa*

b Uropod endopod lateral margin without a deep excision .... *Cirolana*

Genus *Aatolana* Bruce, 1993

Aatolana Bruce, 1993: 2.

Key to species of *Aatolana* recorded from Darwin Harbour.

1 a Frontal lamina with ventral surface flat, anterior margin convex with a small process protruding between the antennal bases; coxa 7 with posterior margin straight or convex. .... *Aatolana ?rapax*

b Frontal lamina with ventral surface not flat, anterior margin with an excavate process; coxa 7 with posterior margin concave .... *Aatolana schioedtei*

Aatolana ?rapax

(Fig. 1 a-b)

?*Aatolana rapax* Bruce, 1993: 5, figs 1-3.

?*Cirolana schioedtei* - Miers 1884: 302 (part).- Holdich, Harrison and Bruce 1981: 581, fig. 10. - Bruce 1986:192, fig. 135 (part) [misidentification, not *Aatolana schioedtei* (Miers, 1884), ? = *Aatolana rapax* Bruce, 1993, see *A. schioedtei* below].

Material examined. 1♂, BMNH 82.1, Arafura Sea, 59-66 m, HMS *Alert* 160 (herein reassigned from syntype series of *A. schioedtei* (Miers)); 78 specimens from station NT-139, AM P44794; 41 specimens from station NT-146, NTM Cr-011499.

Remarks. The material examined matches the original description of *Aatolana rapax* Bruce, 1993 in most characters. It differs in having only 8-10 robust setae on the pleotelson (based on 30 specimens from AM P44794, eight robust setae 40%, nine robust setae 7%, 10 robust setae 53%), not 12-14, and in the uropod endopod having a slightly sinuate lateral margin rather than being straight. Also, the appendix masculina of *A. rapax* extends well beyond the pleopod endopod, whereas in 15 specimens examined from AM P44794 (ranging in size up to 29 mm) the appendix masculina was subequal to the pleopod endopod. However, this character may depend on the size of the specimen because the largest male specimen from AM P44794 (33 mm) has an appendix masculina matching that described for *A. rapax*.

Because of the differences outlined above, it is possible that the material recorded here represents an undescribed species. However, as a number of records of *Aatolana schioedtei* (Miers, 1884) from Australia are probably incorrect (see below), the specific status of the specimens from Darwin are left unresolved until a thorough revision of the *Aatolana* occurring in Australia can be carried out.

Distribution. Arafura Sea and Darwin, Northern Territory; possibly Dampier, Western Australia and Townsville, Queensland. In Darwin

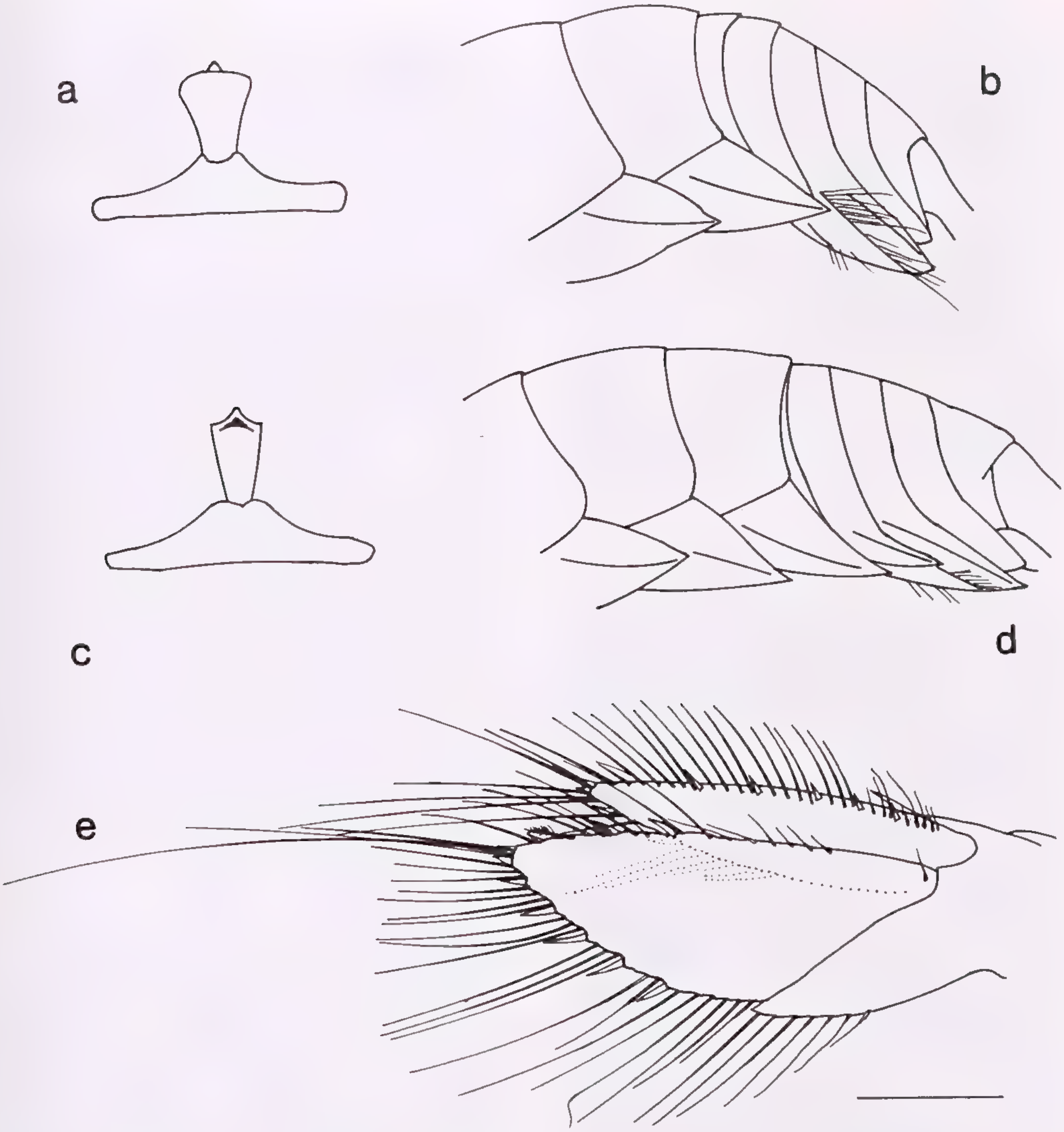

Fig. 1. *Aatolana ?rapax*, ♂, 32 mm, AM P44794: **a**, frontal lamina and clypeus, **b**, coxa 7. *Aatolana schioedtei*, ♂, 28 mm, AM P44795 : **c**, frontal lamina and clypeus; **d**, coxa 7. *Natatolana angula*, ♀, AM P44940: **e**, left uropod. Scale = 0.5 mm.

Harbour the species was collected in depths of 8 to 30 m. *Aatolana rapax* is known from Madang, Papua New Guinea, in depths of 150 to 450 m.

Ecology. In Darwin Harbour *Aatolana ?rapax* was particularly common in the scour zone of all the main channels where gravel sediments predominate. It was collected from between East Point and West Point to Channel Island, Middle Arm. Individuals of this species grow to a relatively large size (over 30 mm) and are extremely efficient scavengers, capable of quickly stripping a fish carcass to the bone (Bruce 1993; personal observation).

Aatolana schioedtei (Miers, 1884)

(Figs 1c, d)

Cirolana schioedtei Miers, 1884: 302, pl. 33, figs A, a, a'. -Hale 1925: 148, fig. 10. -Bruce 1986: 192, fig. 135 (part).

?*Cirolana schiodtei* - Jones and Morgan 1993:142 [*lapsus calami*].

Aatolana schioedtei - Bruce 1993: 5.

Not *Cirolana schioedtei* - Miers 1884: 302 (part). - Harrison, Holdich and Bruce 1981: 581, fig. 10. - Bruce 1986: 192, fig. 135 (part) [misidentification, ? = *Aatolana rapax* Bruce, 1993]; - Nierstrasz 1918: 103, pl. 9, figs 1-2, 16-19. - Nierstrasz 1931: 151 [misidentification, ?=*Aatolana* sp. nov.].

Material examined. Lectotype ♂ designated here, 34 mm, paralectotype ♂, 2 paralectotype ♀♀, BMNH 1941.6.27.1-4, Torres Strait, unknown depth, J.B. Jukes, unknown date; 19♀♀, 14 mancas, 2♂♂ from station NT-130, AM P44795; ♀ from station NT-146, NTM Cr-011500; ♀ from station NT-148, NTM Cr-011501; 6♀♀, 2 mancas from station NT-156, AM P44796.

Remarks. The collection from Darwin Harbour contains two sympatric species of *Aatolana*. Consistent differences between the species are most obvious in the shape of the frontal lamina, coxa 7 and the uropods, the presence or absence of chromatophores, and the presence or absence of fine setae on the dorsal surface of the pleotelson. These differences occur in both sexes and in a range of different sized individuals. One species has a flat frontal lamina, coxa 7 with a straight or convex posterior margin, uropod rami with slightly sinuate lateral margins, no chromatophores and no fine setae on the dorsal margins of the pleotelson. This species was identified as *A. ?rapax* (above).

In order to identify the other species the type specimens of *Aatolana schioedtei* were examined. *Aatolana schioedtei* was based on a syntype series, no holotype was designated and specimens from two localities are mentioned (Arafura Sea and Torres Strait). These specimens are held in the BMNH (registration numbers: ♂, Arafura Sea, BMNH 82.1 (the register and description records two specimens from this locality but only one remains); 4 specimens, Torres Strait, BMNH 1941.6.27.1-4). Using the original description it is difficult to determine which of these specimens the species was based upon. However, the frontal lamina is described as having 'a strong tooth' and the figures show a specimen with fine setae on the dorsal surface of the pleotelson, uropods with strongly sinuate lateral margins and coxa 7 with a concave posterolateral margin. These character states only match the specimens from Torres Strait which also contain a label written in pencil stating 'specimen to be figured'. Miers (1884) stated that Torres Strait specimens all appeared to be males, but this was incorrect as two are male and two are female. The largest male specimen also has the frontal lamina damaged so that the posterior half near the clypeus is narrow as figured by Miers (1884). This specimen (BMNH 1941.6.27.1) is selected here as the lectotype, the other specimens (BMNH 1941.6.27.2-4) become paralectotypes and the type locality is restricted to Torres Strait. The specimen from the Arafura Sea (BMNH 82.1) is excluded from the type series and tentatively reassigned to *A. rapax* Bruce, 1993.

Specimens from Darwin Harbour match *Aatolana schioedtei* in the following important character states: the frontal lamina has a strong "tooth" forward of the antennules and antennae, i.e. it is not flat, there is an excavate extension anteriorly (Fig. 1c); the posterior margin of coxa 7 is distinctly concave (Fig. 1d); the lateral margins of the uropod rami are strongly sinuate, particularly on the exopod (this is most strongly developed on the larger specimens); the pleotelson has fine setae covering much of the dorsal surface of the pleotelson in all but mancas and the smallest adult specimens (less than 18-20 mm long) of both sexes. The material from Darwin Harbour differs from the type specimens in having grey/brown chromatophores present on most of the body (these are particularly dense on the posterior margins of the pereonites, coxae and pleonites, and on the anterior of the uropods and pleotelson). Chromatophores are not apparent in the type material but may have faded while the specimens have been in preservative.

In material identified here as *Aatolana schioedtei*, the form of the frontal lamina is constant and coincides with the other characters outlined above. Therefore, the frontal lamina is a useful character in distinguishing this species from others in the genus. Nierstrasz (1918, 1931) indicated the material he reported differed from that described by Miers (1884) in the shape of the frontal lamina. Consequently, the specimens recorded by Nierstrasz are unlikely to be *A. schioedtei* but the form of the frontal lamina he depicts does not coincide with that of the only other described species of *Aatolana*. Bruce (1986) reported that the frontal lamina occurred in two forms in *A. schioedtei*: with the anterior margin convex, projecting slightly, with a small process protruding between the antennal bases; or with an anterior excavate process. This indicates that he was dealing with more than one species. The male specimen he illustrated from Dampier, Western Australia (Bruce 1986: figs 135 D-G, I-M) probably represents another species, possibly *A. rapax*. Similarly, the single female specimen recorded from Halifax Bay, Townsville, by Holdich *et al.* (1981) is described and figured as having a frontal lamina with a broadly rounded apex and the uropod lateral margins are figured as straight, therefore the specimen probably represents another species, possibly *A. rapax*. The description and figures of Hale (1925) are consistent with the material recorded here as *A. schioedtei*.

Distribution. Previous records of *Aatolana schioedtei* need to be revised; those accepted here include: Western Australia (possibly from Rottnest Island north); Darwin, Northern Territory; Torres Strait. Bruce (1986) indicated the species occurs in depths of 16.3 to 173 m but this information needs to be revised. In Darwin *A. schioedtei* was recorded in depths of 2 to 20 m.

Ecology. *Aatolana schioedtei* is a scavenger but was relatively rare in the trap samples from Darwin Harbour. Only 45 specimens were collected whereas several hundred specimens of *Aatolana ?rapax* were obtained. *Aatolana schioedtei* was collected in Fannie Bay, off Bleesers Creek and Channel Island, from areas where terrigenous sand primarily comprises the habitat. *Aatolana schioedtei* and *A. ?rapax* were sympatric in the vicinity of Channel Island.

Genus *Cartetolana* Bruce, 1981

Cartetolana Bruce, 1981: 959; 1986: 209.

Cartetolana integra (Miers, 1884)

Cirolana lata var *integra* Miers, 1884: 304.

Cirolana lineata Potts, 1915: 89, fig. 6, pl. 1, fig. 4.

Cartetolana integra - Bruce 1986: 212, figs 148, 149.

Material examined. ♀ (ovigerous), NTM Cr-004485, off East Point, 12°24.63'S 130°48.48'E, Darwin, Northern Territory, from *Comanthus parvicirrus*, L. Vail *et al.*, 26 November 1986; ♀, NTM Cr-003447, Casuarina Beach, Darwin, Northern Territory, storm debris, C. Hood, 22 January 1986.

Remarks. Both specimens match the redescription of Bruce (1986) quite closely, however, differences include: the uropod exopod is slightly longer than the endopod, rather than being subequal to it; the uropods have a greater number of robust setae, this is most noticeable on the lateral margin of the exopod on the specimen from NTM Cr-004485 which has approximately 10 robust setae, not five; the specimen from NTM Cr-004485 also has two robust setae on the propodal palm of pereopod 1, not one. Both specimens have the banded chromatophore pattern described by Bruce (1986) rather than the striped pattern.

Distribution. *Cartetolana integra* has previously been recorded from the Aru Isles, Arafura Sea; Broome and Cape Naturaliste, Western Australia; Cobourg Peninsula, Northern Territory; One Tree Island and Hannibal Island, Queensland; Madang Lagoon, Papua New Guinea.

Ecology. This species is a commensal of crinoids (Bruce 1986) and has also been collected from shallow subtidal coral reef substrates Bruce (1995).

Genus *Cirolana* Leach, 1818

Cirolana Leach, 1818: 347.- Bruce 1986: 139; 1993: 2. - Brusca, Wetzer and France 1995: 17.

Nelocira Leach, 1818: 347.

Remarks. Six species of *Cirolana* were collected which could not be identified as any of the species previously recorded from Australia. Two species are in the "Tuberculate group" (*Cirolana* sp. 7, 8), three species belong to the "*Cirolana parva* group" (*Cirolana* sp. 2, 5, 6) and one species (*Cirolana* sp. 1) shows no affinity to any of the informal subgroups proposed by Bruce (1986). These species are possibly undescribed. Voucher specimens have been lodged in the AM (P44797-44819) and the NTM (Cr-011502-011507). Their specific status has been left unresolved until a more thorough study of the genus *Cirolana* can be carried out. Except in the key to species, the systematics of these unidentified taxa is not dealt with further in this report. All of these unidentified taxa were collected in baited traps. *Cirolana* sp. 1, 2, 5 and 6 were generally associated with the rock or coral reef habitats, occurring from the harbour mouth to Shell Islands, East Arm and Channel Island, Middle Arm. They were also collected in the scour zone of the channels, where gravel sediments are prevalent, but were usually less abundant in these locations. *Cirolana* sp. 7 was collected in a limited number of samples from habitats including a shallow, muddy, mangrove lined creek in Woods Inlet and muddy intertidal sediments. *Cirolana* sp. 8 was collected from the scour zone of the channels.

Key to species of *Cirolana* recorded from Darwin Harbour, based on adult male specimens after Bruce (1986).

1 a Pleon and pleotelson dorsal surfaces with distinct tubercles and/or carinae 7
b Pleon and pleotelson dorsal surfaces without distinct tubercles or carinae 2
2 a Pereopod 1 with a dense setose fringe on the posterior margin of the ischium, merus, carpus and propodus ... *Cirolana mekista*
b Pereopod 1 without a dense setose fringe on the posterior margin of any articles 3
3 a Antennule peduncular articles 1 and 2 at least partially fused, peduncle 3-articulate 4
b Antennule peduncular articles 1 and 2 clearly articulating, peduncle 4-articulate .... *Cirolana* sp. (5)
4 a Pleotelson with six robust setae. .... *Cirolana stenoura*
b Pleotelson with more than six robust setae...5
5 a Pereopod 1 merus posterior margin with four nodular robust setae; appendix masculina not extending to the distal extremity of the plumose marginal setae on the endopod of pleopod 2........................... ....*Cirolana improceros*
b Pereopod 1 merus posterior margin with more than four nodular robust setae; appendix masculina extending subequal to, or beyond, the distal extremity of the plumose marginal setae on the endopod of pleopod 2 6
6 a Pereopod 1 merus posterior margin with five nodular robust setae; appendix masculina extending beyond the distal extremity of the plumose marginal setae on the endopod of pleopod 2, bent medially .... *Cirolana* sp. (6)
b Pereopod 1 merus posterior margin with six nodular robust setae; appendix masculina extending subequal with the distal extremity of the plumose marginal setae on the endopod of pleopod 2, straight .... *Cirolana* sp. (2)
7 a Pleotelson dorsal surface with two curved carinae ....*Cirolana kendi*
b Pleotelson dorsal surface without curved carinae 8
8 a Pleotelson dorsal surface with a dense patch of fine setae; penes well developed .... *Cirolana* sp. (1)
b Pleotelson dorsal surface without fine setae; penes absent, vas deferens opening flush to surface of sternite 9
9 a Pleotelson lateral margins strongly sinuate, apex narrowly rounded with six robust setae .... *Cirolana capricornica*
b Pleotelson lateral margins weakly sinuate, apex broadly truncate with eight robust setae 10
10 a Pereonite 7 posterior margin, pleonites and pleotelson with numerous strongly defined tubercles .... *Cirolana* sp. (8)
b Pereonite 7 posterior margin, pleonites and pleotelson with few weakly defined tubercles .... *Cirolana* sp. (7)

Cirolana capricornica Bruce, 1986

Cirolana capricornica Bruce, 1986: 151, fig. 102.

Material examined. 133 specimens from station NT-157, AM P44820; ovigerous ♀, NTM Cr-002664, Channel Island, Darwin, Northern Territory, 12°33.0'S 130°52.4'E, coral reef, gravel, sand, ELWS, A.J. Bruce and M. Burke, 7 Feb. 1985, AJB-22.

Distribution. *Cirolana capricornica* has previously been recorded from the Abrolhos Islands and Cape Jaubert, Western Australia; Cobourg Peninsula, Northern Territory; Torres Strait; Great Barrier Reef including Heron Island to Lizard Island, Queensland; in depths of 0 to 32m.

Ecology. This species is a scavenger and was widely distributed throughout Darwin Harbour and off the beaches to the north-east of Darwin. It was collected from rock, coral reef and the range of sediment substrates, from intertidal depths on mud to the scour zone of the main channels where gravel sediments are prevalent. The broad habitat distribution found in Darwin differs from the ecology of the species at Lizard Island, Queensland, where it is primarily restricted to medium or coarse grained subtidal sediments and virtually absent from fine grained sediments, reefs and intertidal habitats (Keable 1992, 1995). At Heron Island, Queensland, *Cirolana capricornica* was collected in baited traps set on beach rock and appeared to inhabit that area rather than areas of living and dead coral (Bruce 1980 as *C. pleonastica*).

Cirolana improceros Bruce, 1986

Cirolana improceros Bruce, 1986: 182, figs 125, 126.

Material examined. six paratype specimens, AM P28780, Bampfield Head, Thursday Island, Queensland, 10°43'S 142°07'E, beam trawl over seagrass beds, P.C. Young, CSIRO Fisheries, 19 April 1979, 22:00 hours; ♂, NTM Cr-010864, Lee Point, Darwin, Northern Territory, 12°19.5'S 130°52.5'E, rocky outcrop with pools, LWS, A.J. Bruce, 23 November 1982, AJB/18; 25 ♂♂, 24 ♀♀, NTM Cr-002033, Dudley Point, Darwin, Northern Territory, LWS, A.J. Bruce, 26 September 1984.

Remarks. There are six paratype specimens at the AM, P28780: one is a male, four are females and one is a cymothoid isopod that has apparently been included erroneously. *Cirolana improceros* was described by Bruce (1986) as having very slightly protruding penes set very close together. The male paratype specimen does not support this statement, the vas deferens appear to open flush to the surface of sternite 7 as in other species from Australia (Bruce 1986: 184). The specimens recorded here (NTM Cr-010864, NTM Cr-002033) were identified on the basis of the shape of the appendix masculina, which is comparatively short and has an acuminate tip, and the presence of only four nodular robust setae on the posterior margin of the merus of pereopod 1.

Distribution. *Cirolana improceros* has previously been recorded from Port Essington and Cobourg Peninsula, Northern Territory; Thursday Island, Hinchinbrook Island and Townsville, Queensland; in depths of 0 to 13 m.

Ecology. This species has previously been recorded from baited traps (Bruce 1986), therefore, it is surprising that it was not collected using this method in the present study. Possibly the species has a restricted distribution within Darwin Harbour.

Cirolana kendi Bruce, 1986

Cirolana kendi Bruce, 1986: 156, fig. 105.

Material examined. 6 ♂♂, ♀ from station NT-119, AM P44821.

Remarks. There were only two specimens available for the original description and the holotype was described as having five robust setae on the pleotelson. In cirolanids there is usually an even number of robust setae present in this position (Bruce 1993: 11). In the material examined here, one male has five robust setae on the pleotelson margin and the remainder of the specimens have six. Twenty of the specimens reported by Keable (1992, 1995) from the type locality were also examined, 90% of these had six robust setae on the pleotelson margin and 10% had five.

Distribution. *Cirolana kendi* has previously been recorded from Lizard Island, Queensland, in depths of 3 to 22 m.

Ecology. This species is a scavenger. It was extremely rare in Darwin Harbour, only seven specimens were collected. *Cirolana kendi* also has a restricted distribution at Lizard Island where it is abundant but confined to areas of medium grained sediment (Keable 1992, 1995).

Cirolana mekista Bruce, 1986

Cirolana mekista Bruce, 1986: 185, figs 127, 128.

Material examined. 51 specimens including 13 ♂♂ from station NT-146, AM P44822; 525 specimens from station NT-157, AM P44823; 3 ♂♂, 2 ♀♀ , NTM Cr-00280, East Point, Darwin Harbour, Northern Territory, dead coral, LTL, A.J. Bruce, 1 January 1983, AJB/11; ♂, NTM Cr-005072, Fannie Bay, Darwin, Northern Territory, 4 m, I. Archibald, 27 April 1987; 2 ♂♂, NTM Cr-002664, Channel Island, Darwin Harbour, Northern Territory, coral reef, ELWS, A.J. Bruce, 7 February 1985, AJB 22; ♂, ♀, NTM Cr-005820, Dudley Point, Darwin Harbour, Northern Territory, intertidal sponges, ELWS, P. Horner, 11 December 1982; ♂, NTM Cr-001294, 11°08.5'S 132°18.8'E, 6 m, J. Hooper, 1 May 1982, CP/33.

Remarks. Males of this species show variation in the development of the setal fringe on pereopod 1 and the length of the appendix masculina as they mature (Bruce 1986). In smaller specimens the setal fringe is only sparsely developed or absent. This is the case with specimens from Cr-002280, Cr-002664, Cr-005820 and Cr-001294 which were only tentatively identified as *Cirolana mekista*.

Distribution. *Cirolana mekista* has previously been recorded from Broome and Port Hedland, Western Australia; Port Essington, Cobourg Peninsula, Northern Territory; Gladstone, Townsville and Cairns, Queensland; in depths of 0 to 20 m.

Ecology. This species is a scavenger and was particularly common in Darwin Harbour among rock and coral reef habitats of the main harbour arms. It was also collected in the scour zone of the channels where gravel sediments predominate. *Cirolana mekista* has been collected from the mouth of the harbour to Shell Islands, East Arm and Channel Island, Middle Arm.

Genus *Excirolana* Richardson, 1912

Excirolana Richardson, 1912: 201.- Bruce 1986: 39.- Brusca, Wetzer and France 1995: 47.
Pontogeloides Barnard, 1914: 355a.

Excirolana orientalis (Dana, 1853)

Cirolana (*Eurydice*) *orientalis* Dana, 1853: 773, pl. 51.

Excirolana orientalis - Bruce 1986: 41, fig. 24.

Material examined. 2 ♂♂, 2 ♀♀, 3 mancas from station NT-161, AM P44824; 3 ♀♀, NTM Cr-010001, Fannie Beach, Darwin, Northern Territory, 12°24.9'S 130°49.7'E, 0-2 m, R. Williams, 24 March 1992; 2♀♀ (with oostegites), NTM Cr-003679, Lee Point, Darwin, Northern Territory, stream over sand, HWS, A.J. Bruce, 19 August 1985; ♂, manca, NTM Cr-000357, Casuarina Beach, Darwin, Northern Territory, sand, MTL, N.L. Bruce, 21 December 1982; 5 ♂♂, 8 ♀♀, NTM Cr-000357, Casuarina Beach, Darwin, Northern Territory, beach sand, LW, N.L. Bruce, 21 May 1983; ♀, NTM Cr-000252, Fannie Bay, Darwin, Northern Territory, muddy sand pool, LW, P. Alderslade, September 1982.

Remarks. The antennal peduncle of this species was described by Bruce (1986, Table 2) as 4-articulate although his figure 24B indicates five articles, the first of which may be fused to the cephalon. Hale (1925) and Holdich *et al.* (1981) show five articles in their figures. In the specimens examined here a very short proximal article is visible in ventral view, there is a small pit where this articulates with the cephalon and the peduncle is therefore considered to be 5-articulate.

Distribution. *Excirolana orientalis* has been recorded widely through the Indo-West Pacific including eastern Africa to the Philippines and Papua New Guinea, it is also known from the Solomon Islands (N. Bruce *in litteris*). In Australia the species was previously known from the Cobourg Peninsula, Northern Territory; Lizard Island and Townsville, Queensland. This species occurs intertidally.

Ecology. In Darwin *Excirolana orientalis* was collected from intertidal beach sediments and beach rock both within the harbour and on the coast to the north-east. This species was not particularly abundant in trap samples relative to the catches of some of the other scavengers occurring intertidally and subtidally.

Genus *Limicolana* Bruce, 1986

Limicolana Bruce, 1986: 214.

Limicolana dinjerra Bruce, 1986

Limicolana dinjerra Bruce, 1986: 215, figs 151-152.

Material examined. 73 specimens from station NT-181, AM P44825; ♂, 3 ♀♀, manca from station NT-149, AM P44826; 4 ♂♂, 4 ♀♀, NTM Cr-003677, Meckitt's Creek, Darwin, Northern Territory, mangrove, J.R. Hanley, 9 June 1982.

Remarks. The majority of specimens from AM P44825 have eight robust setae on the pleotelson margin although occasional specimens have nine or 10. Large specimens from AM P44826 and NTM Cr-003677 have approximately four raised spinicles on the dorsal surface of the antennal peduncular article 5, four spinicles on the cephalon and two spinicles medially on the dorsal surface of pereonite 3.

Distribution. This species was previously known from Derby, Western Australia and the East Alligator River, Northern Territory. It occurs intertidally.

Ecology. *Limicolana dinjerra* is the only species in the genus. It has not previously been collected using a baited trap and was not known to feed as a scavenger until the present study. *Limicolana dinjerra* is apparently restricted to habitats among mangroves and is known to occur in burrows in mud banks (Bruce 1986).

Genus *Natatolana* Bruce, 1981

Natatolana Bruce, 1981: 957; 1986: 52. - Brusca, Wetzer and France 1995: 74.

Key to species of *Natatolana* recorded from Darwin Harbour after Bruce (1986).

1 a Uropod endopod lateral margin with a prominent excision ....*Natatolana variguberna*
b Uropod endopod lateral margin straight or smoothly curved, without a prominent excision 2
2 a Pleotelson with six or less robust setae on margins 3

b Pleotelson with more than six robust setae on margins 4

3 a Pleotelson posterolateral margins strongly convex, apex forming an obtuse angle; uropod endopod lateral margins strongly convex, apex relatively broad and rounded; appendix masculina apex bluntly rounded. .... *Natatolana taiti*

b Pleotelson posterolateral margins weakly convex, apex forming an acute angle; uropod endopod lateral margins weakly convex, apex relatively narrow and acute; appendix masculina apex with a distinct acute projection ....*Natatolana thalme*

4 a Pleotelson posterolateral margins straight 5

b Pleotelson posterolateral margins smoothly curved 6

5 a Pleotelson posterolateral margins merging smoothly with anterolateral margins, meeting at a very acute apex; antennal peduncular article 4 with a row of long slender setae along entire posterolateral margin .... *Natatolana lowryi*

b Pleotelson posterolateral margins abruptly angled to anterolateral margins, meeting at an acute apex; antennal peduncular article 4 without a row of long slender setae along entire posterolateral margin .... *Natatolana luticola*

6 a Antennae extending less than halfway along the body; pleonite 2 posteroventral angle subequal to posterodorsal angle .... *Natatolana angula*

b Antennae extending over halfway along the body; pleonite 2 posteroventral angle formed into a long curved process extending posteriorly to posterodorsal angle .... *Natatolana tenuistylis*

Natatolana angula Bruce, 1986
(Fig. 1e)

Natatolana angula Bruce, 1986: 106, fig. 73.

Material examined. Two paratypes, AM P32380, Calliope River, Gladstone, Queensland, 24°01'S 150°59'E, P. Saenger and J. Moverly, 1975. Series of 7 ♂♂, 9 ♀♀, AM P44827-44835, north-west shelf, Western Australia, between 19°05.0'-19°56.9'S 117°53.6'-118°57.8'E, sled and beam trawl, 39-83 m, CSIRO, 1983. ♀, NTM Cr-005818, north-west shelf, 19°31'S 118°49'E, 40 m, FRV *Soela* AS 0283, 26 April 1983, NWS-9. Darwin, Northern Territory, baited trap series, AM P44939-44942 - 3 ♂♂, 9 ♀♀ from station NT-119; 7 ♂♂, 10 ♀♀ from station NT-123; 3 ♂♂, 8 ♀♀, 4 mancas from station NT-139; 3 mancas, ♀ from station NT-158. ♀, NTM Cr-002279, Oxley Island, Northern Territory, 10°59.0'S 132°48.8'E, LWS, J. Robinson, 19 October 1982, NY/8; 5 ♂♂, NTM Cr-002543, Weed Reef, Darwin Harbour, NT, exposed rocky reef, LWS, J. Baxter, 9 September 1985, AJB-20; 2 ♀♀, 2 mancas, NTM Cr-003372, Dudley Point Reef, Darwin, Northern Territory, silty reef flat pool, A.J. Bruce, 18 October 1985, AJB-29. Manca, AM P44836, Thursday Island, Torres Strait, Queensland, 10°35.33'S 142°13.14'E, baited trap, unknown substrate - probably sediment, 9 m, S. Keable, 31 January 1993, QLD-785; ♂, 3 ♀♀, AM P44837, Bet Reef, Torres Strait, Queensland, 10°10.54'S 143°33.54'E, baited trap, unknown substrate, 20 m, S. Keable, 30 January 1993, QLD-784. Series of 3 ♂♂, 3 ♀♀, manca, QM W18843 W18854 W18858 W18861 W18872 W18883 W20571 Gulf of Carpentaria, between 10°12.8'-15°26.1'S 136°19'-141°11.9'E, grab, 17-58 m, FRV *Southern Surveyor*, 1990-91. ♂, QM W18842, Shelburne Bay, Queensland, 11°22'S 142°55.6'E, grab, FRV *Southern Surveyor*, 21 m, stn 72, 1 January 1991; ♀, QM W18852, Shelburne Bay, Queensland, 11°02.9'S 142°52.8'E, grab, FRV *Southern Surveyor*, 21 m, 20 Nov. 1991. Series of 11 ♂♂, 15 ♀♀, AM P44838-44851 and P40176, Lizard Island, Queensland, 14°40'S 145°28'E, baited trap, sediments, 0-24 m, S. Keable *et al.*, 1989-90. Manca, QM W18294, Halifax Bay, Townsville, Queensland, 19°07'S 146°36'E, James Cook University Three Bays Survey, stn 42A, 25 August 1976; ♀, QM W18903, Gladstone, Queensland, 23°51'S 151°14'E, dredged, QEC Gladstone Survey, January 1976.

Remarks. This species was described as having 12 robust setae on the pleotelson margin. The two paratypes held at the AM, P32380, were examined and found to vary from this description. One of the paratypes has nine robust setae on the pleotelson, the other specimen has 11. Neither specimen shows obvious signs of damage to the pleotelson. The majority of the material examined here has 10 robust setae on the pleotelson, occasional specimens have eight or nine robust setae and only three specimens have 12 (NTM Cr-002279, NTM Cr-003372 and AM P44839). Also, the robust setae present on the uropod rami are incorrectly described by Bruce (1986), the description should read: endopod medial margin with five robust setae, apex with two robust setae, lateral margin with three robust setae; exopod medial margin with two robust setae, apex with two robust setae, lateral margin with five robust setae.

Character states which were found to be particularly useful in identifying this species include; a complete interocular furrow (although this is faint in some specimens); a narrow, medially constricted frontal lamina with expanded angular apex; a short antenna reaching to the posterior of pereonite 3 when flattened against the body, 0.4 x the length of the body; slightly rounded posterolateral margins on pleonite 4 with a small excision at the ventral edge; a short, tapering appendix masculina with a bluntly rounded apex; and the straight lateral margins of the uropod exopod. Many specimens also have a tuft of extremely long slender setae at the apex of the uropod endopod (Fig. 1e). These setae are longer than the uropod rami and quite distinctive when present. However, these setae are fragile and appear to have been broken off some of the specimens examined.

Distribution. Previous records of *Natatolana angula* are from Darwin, Northern Territory; Halifax Bay, Townsville, also Lizard Island and the mouth of Calliope River, Queensland. This distribution is now expanded to include localities throughout northern Queensland to Torres Strait, the Northern Territory and north-western Australia. The species occurs in depths of 0 to 83 m.

Ecology. *Natatolana angula* is a scavenger and was widely distributed in Darwin Harbour and also off the beaches to the north-east of Darwin. It was collected on a range of sediments occurring in the intertidal zone to the scour zone of the main channels, it was also occasionally found in low numbers among rock or coral reef habitats. Although *N. angula* was a common scavenger it was rarely the numerically dominant species in trap samples.

Natatolana lowryi sp. nov.
(Figs 2-4)

Type material. HOLOTYPE: ♂, 15.3 mm, NTM Cr-011523. Paratypes: ♀, manca, AM P44852; ♂, NTM Cr-011508; ♂, ZMUC CRU-1713; ♂, USNM 264079. Type locality: Middle Arm, west of Channel Island, Darwin Harbour, Northern Territory, Australia, 12°33.7'S 130°50.7'E, baited trap, unknown substrate - probably muddy sediment, 2 m, S. Keable, 12-13 July 1993, NT-148.

Additional material. Series from NTM Marine Ecology Department Study, Melville Bay, Gove, Northern Territory, 12°11.75'S 136°41.28'E, grab, R. Hanley *et al.* - ♀, NTM Cr-011509, 8 m, 20 March 1992, A34Wa; ♀, NTM Cr-011510, 9.4 m, 21 March 1992, A35; ♂, NTM Cr-011511, 9.4 m, 21 March 1992, A35Wd; ♀, NTM Cr-011512, 9.8 m, 21 March 1992, A36; manca, NTM Cr-011513, 5.5 m, 24 March 1992, C13Wa; ♀, NTM Cr-011514, 4.7 m, 24 March 1992, C14Wa; ♂, NTM Cr-011515, 6.5 m, 25 July 1991, D4a. ♂, QM W18856, Gulf of Carpentaria, Queensland, 12°59.1'S 138°42'E, grab, 55 m, FRV *Southern Surveyor*, 10 December 1990, stn 88; ♂, QM W18884, Gulf of Carpentaria, Queensland, 12°31.3'S 138°41.8'E, grab, 53 m, FRV Southern Surveyor, 9 December 1990, stn 87.

Material described. Holotype.

Diagnosis. *Cephalon*: rostral point present. Eyes present. Interocular furrow extending from eye to eye. *Frontal lamina*: lateral margins straight, narrowing anteriorly. *Labrum*: without lamina projection. *Antenna*: 0.2 x length of body, reaching to posterior of pereonite 1; flagellum without digitate process on articles. *Coxal plates*: with furrows incomplete on coxae 3 and 4, absent on other coxae; coxa 2 with anteroventral corner not produced into acute tooth. *Pleonite 2*: ventral posterolateral margin acute, not formed into curved process. *Pleonite 3*: posterolateral margins apex acute. *Pleonite 4*: posterolateral margins apex forming broad acute point. *Pleotelson*: anterodorsal depression absent; anterolateral margins almost straight and angling posteriorly toward midline; posterolateral margins straight, not markedly angled to anterolateral margins; apex not produced; approximately 12-14 robust setae present. *Pereopod 2*: propodal palm without robust setae. *Pereopod 7*: basis narrow; anterior margin slightly convex; posterior margin convex. *Penes*: absent. *Pleopod 2 appendix masculina*: extending beyond tip of endopod; width slender; margins very slightly curved laterally, parallel along entire length; apex not at angle to margins, acute. *Uropods*: exopod short; endopod lateral margin slightly sinuate; exopod lateral margin convex, robust setae present.

Description. Male. *Overall body form*: 15.3 mm long; narrow, approximately 3 x as long as wide. Colour translucent white in alcohol. Chromatophores absent.

Cephalon: submarginal cephalic furrow well developed, runs entire length of margin. Eyes present, moderate in size; with eight ocelli in

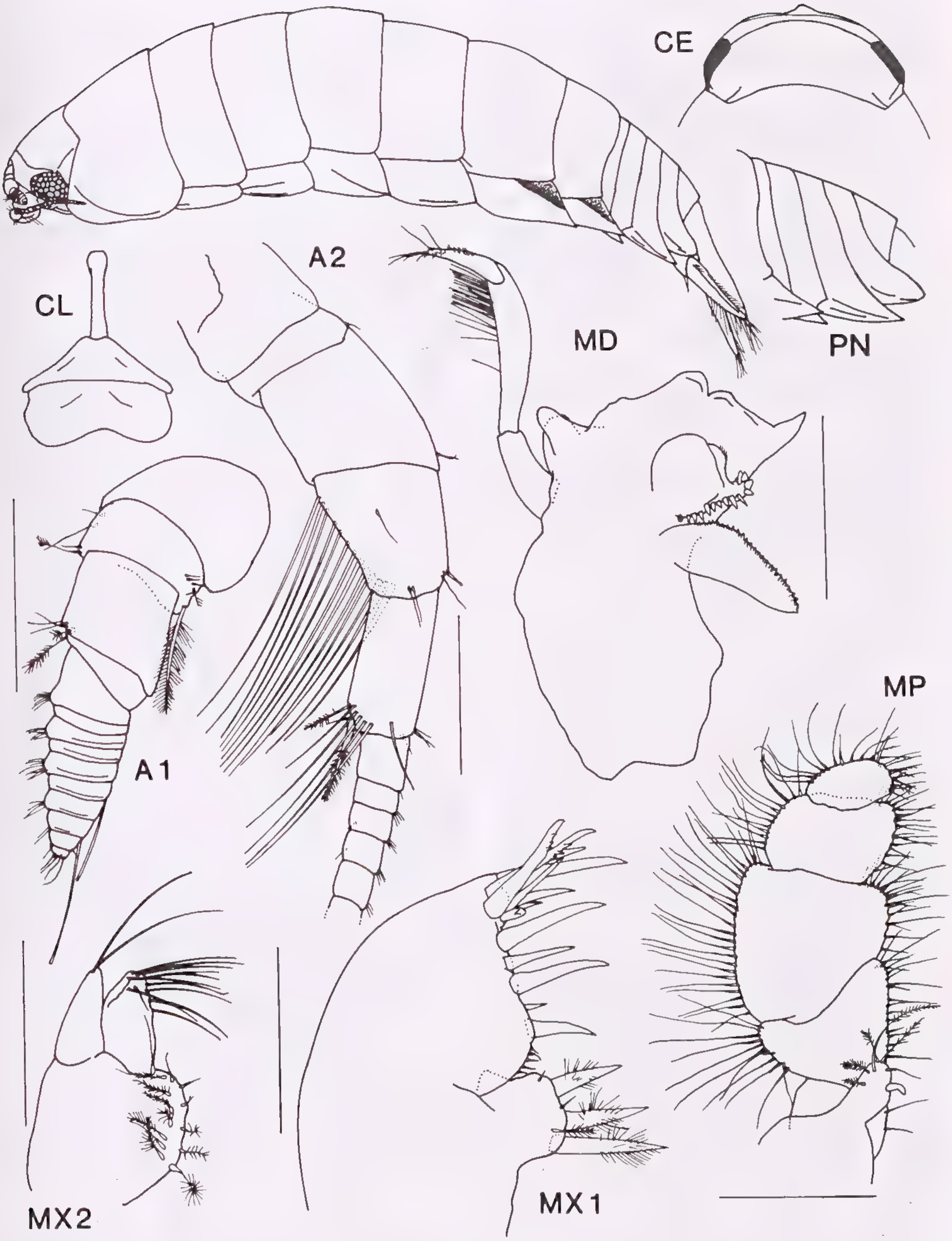

Fig. 2. *Natatolana lowryi* sp. nov., holotype. Scales = 0.5 mm.

horizontal diameter; with six ocelli in vertical diameter; round; colour red in alcohol. Interocular furrow well developed, extending from eye to eye.

Frontal lamina: elongate, approximately four x longer than basal width; lateral margins straight, narrowing anteriorly; anterior apex expanded, rounded.

Antennule: peduncular article 1 longer than article 2; article 2 with one large pappose seta; article 3 long, larger than article 1 or 2 but shorter than their combined lengths. Flagellum shorter than peduncle, 10-articulate; proximal article longest; subsequent articles alternating in length from short to long at proximal end but at distal end articles become subequal in length.

Antenna: short, 0.2 x as long as body; when extended against the body reaching to posterior of pereonite 1. Peduncular article 2 shorter than article 3; article 4 subequal in length to article 5, with one row of approximately 13 long slender setae along the length of the posterolateral margin; article 5 with two pappose setae and approximately five long slender setae at posterodistal angle. Flagellum 23-articulate.

Mandible: incisor with broad middle tooth; palp article 2 of medium length, approximately twice the length of article 3; setal row with 15 robust setae.

Maxillule: endopod with three robust and one smaller pappose setae; exopod with 13 robust setae on gnathal surface.

Maxilla: palp with two slender setae; endopod with four slender and 11 plumose setae; exopod with 14 slender setae.

Maxilliped: palp moderately setose; article 3 length subequal to breadth; article 4 length less than breadth; article 5 length greater than breadth. Endite with one coupling hook and five plumose setae.

Pereon: ornamentation 1 strongly developed furrow on lateral margins of pereonite 1; pereonites 1, 4-6 subequal and longest, 2-3 and 7 subequal.

Coxal plates: with furrows incomplete on coxae 3 and 4, absent on other coxae. Coxal points variously developed; pereonite 1 and coxae 2-3 with rounded posteroventral margins, coxae 4-7 with increasingly produced, broad, acute posteroventral margins.

Pleonites: ornamentation 2 weakly developed furrows on lateral margins of pleonite 3, 1 on lateral margins of pleonite 4. *Pleonite 2*: dorsal posterolateral margin subequal with ventral posterolateral margin. *Pleonite 4*: posterolateral margins produced posterior to those of pleonite 3; apex forming broad acute point.

Pleotelson: narrow, length 1.01 x basal width; anterodorsal depression absent; anterolateral margins almost straight and angling posteriorly toward the midline; posterolateral margins straight, not markedly angled to anterolateral margins, meeting at an acute angle; apex not produced, lateral margins meeting smoothly to a point; robust setae present, 11 altogether, five on one posterolateral margin and six on the other; marginal plumose setae present, moderately abundant, on posterolateral margins only.

Pereopods 1-6: without conspicuous elongated robust setae. *Pereopod 1*: basis with sparse slender setae on anterior margin. Ischium anterodistal angle without robust setae but with numerous long slender setae; posterior margin without robust setae, slender setae present, abundant. Merus anterodistal angle with one robust seta and one row of slender setae; posterior margin straight, with 11 robust setae and two slender setae. Merus-carpus with only carpus proportionally shorter than on pereopods 2 and 3. Carpus short, less than half the length of the propodus; with two robust setae and one slender seta present. Propodus subequal to that of pereopods 2 and 3; with five robust setae on palm; slender setae present on margin. Dactylus short, not as long as propodus; slender. *Pereopods 2-3*: merus and carpus with robust setae more numerous and larger than on pereopod 1. *Pereopod 2*: ischium anterodistal angle without robust setae; posterior margin with two robust setae. Merus anterodistal angle with two robust setae; posterior margin with 12 robust setae. Carpus with six robust setae. Propodus without robust setae on palm. *Pereopod 3*: ischium anterodistal angle with one robust seta; posterior margin without robust setae. Merus anterodistal angle without robust setae; posterior margin with 12 robust setae; robust setae longer than on pereopod 1. Carpus with six robust setae. Propodus without robust setae on palm. *Pereopod 4*: propodus with two robust setae on palm; three robust setae opposing dactylus. *Pereopods 5-7*: relative morphology dissimilar, basis of pereopod 5 narrower and not as setose as that of 6 and 7, ischium to carpus of pereopods 5 and 6 distinctly broader and with a greater number of robust setae than pereopod 7. *Pereopod 6*: basis broader than that of pereopod 7; propodus longer than that of pereopod 7. *Pereopod 7*: basis narrow, width 0.46 x length; anterior margin slightly convex, with very long plumose setae along entire length; medial carina with short plumose setae along entire length; posterior margin convex, with short, slender setae along proximal quarter only; posterodistal angle with long plumose setae. Ischium anterior margin with slender setae present;

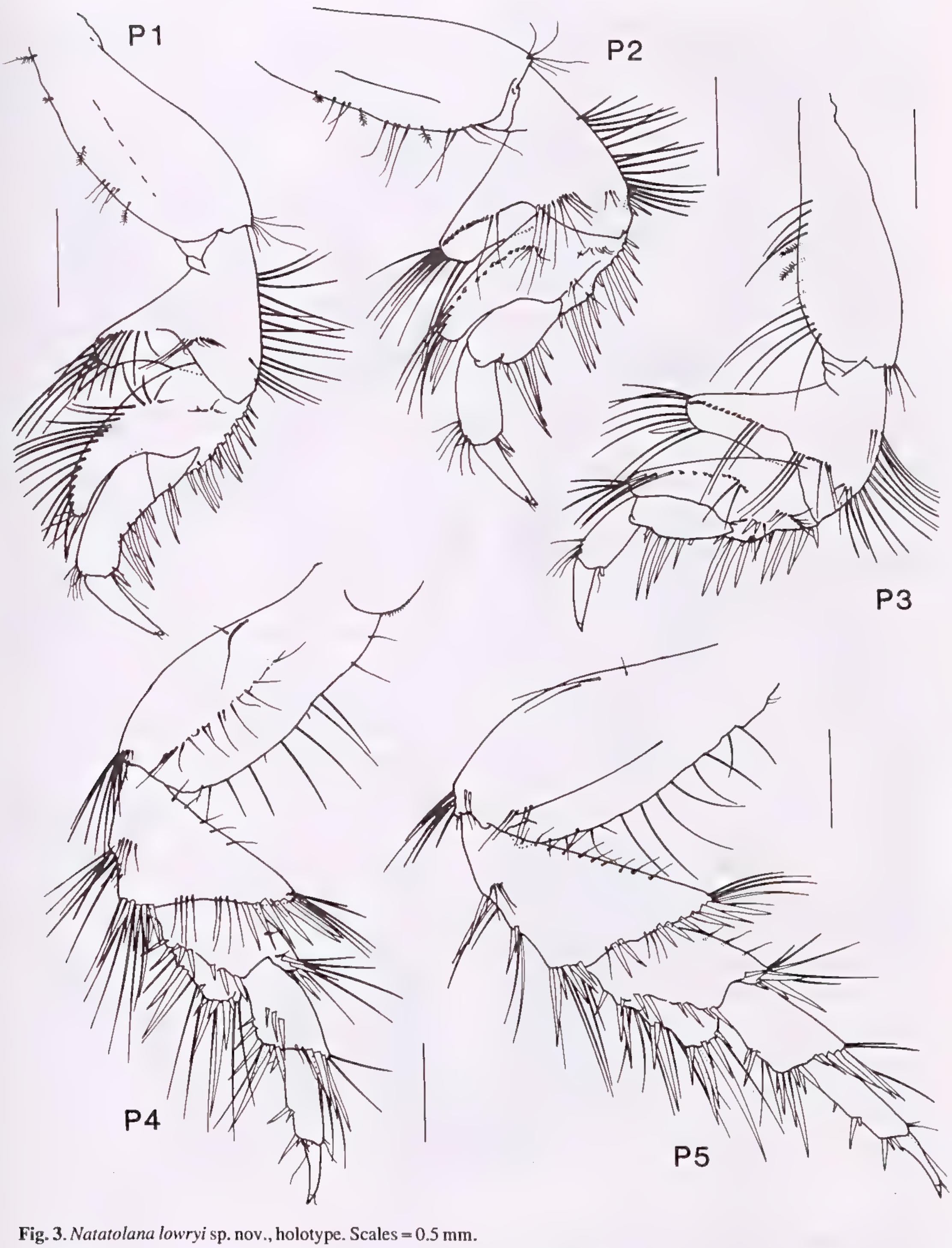

Fig. 3. *Natatolana lowryi* sp. nov., holotype. Scales = 0.5 mm.

anterodistal angle without robust setae, slender setae present; posterior margin with a few robust setae present submarginally, plumose setae present; posterodistal angle without robust setae, slender setae present. Merus anterior margin with one slender seta present; anterodistal angle with three robust setae, slender setae present; posterior margin with four robust setae, slender setae present; posterodistal angle with six robust setae, slender setae absent. Carpus anterodistal angle

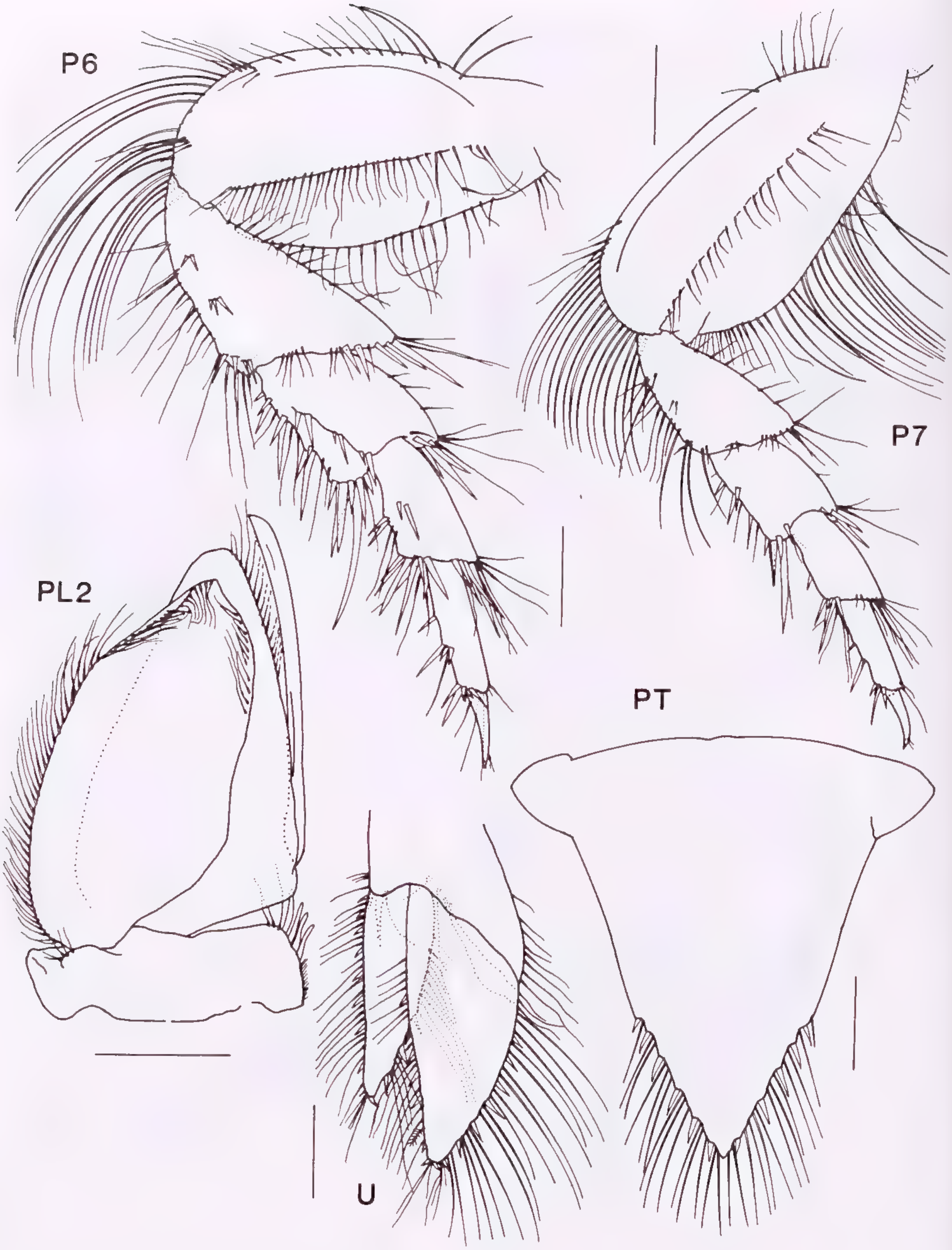

Fig. 4. *Natatolana lowryi* sp. nov., holotype. Scales = 0.5 mm.

without robust setae, slender setae present; posterior margin with one robust seta, slender setae absent; posterodistal angle with five robust setae, slender setae present. Propodus shorter than carpus; posterior margin with three robust setae, slender setae absent; posterodistal angle with four robust setae; anterodistal angle with slender setae present.

Penes: absent, vasa deferentia opening flush to surface of sternite 7.

Pleopods: pleopods 1-2 peduncles with four coupling hooks; exopod broader than endopod; pleopod 1 exopod margin rounded; endopod margin narrow at apex. *Pleopod 2 appendix masculina*: arising sub-basally; extending beyond tip of endopod; 1.09 x length of endopod; margins very slightly curved laterally, approximately parallel along entire length; apex not at an angle to margins, acute. *Pleopods 3-5*: exopod suture present. *Pleopod 5*: endopod with proximal lobe on medial margin absent.

Uropods: subequal with the length of the pleotelson; peduncle ventrolateral angle with two robust setae. Endopod lanceolate; medial margin convex, with seven robust setae, long plumose setae present along entire length; apex with two robust setae; lateral margin slightly sinuate, with six robust setae, short plumose setae present on distal three quarters. Exopod short, 0.77 x the length of the endopod; medial margin convex, with three robust setae, long plumose setae present on distal four fifths; apex acute, with two robust seta; lateral margin convex, with eight robust setae, plumose setae present on entire length.

Sexual dimorphism. Females differ from males only in the primary sexual characters.

Variation. The holotype specimen has 11 robust setae on the pleotelson margin. In cirolanid isopods the robust setae on the pleotelson margin are nearly always paired (Bruce 1993: 11). The majority of specimens in the type series have 12 robust setae on the pleotelson while the other material mostly has 14 robust setae on the pleotelson although several specimens have 13.

Size range. Up to approximately 20 mm.

Remarks. *Natatolana lowryi* is most similar to *N. luticola* (Holdich, Harrison and Bruce, 1981). It is separated from this species by the posterolateral margins of the pleotelson being less markedly angled to the anterolateral margins and by having a more acute angle at the apex of the pleotelson. The fringe of long slender setae on the posterior margin of the antennal peduncular article 4 is also a distinctive character state for this species.

Distribution. This species is known from Darwin and Gove, Northern Territory, and the Gulf of Carpentaria; in depths of 2 to 55 m.

Ecology. *Natatolana lowryi* is a scavenger but was extremely rare in the trap samples from Darwin Harbour, only six specimens were collected from the vicinity of Channel Island.

Etymology. This species is named after Dr James Lowry (The Australian Museum), in recognition of the help he has given me during this study and in a number of other investigations.

Natatolana luticola
(Holdich, Harrison and Bruce, 1981)

Cirolana luticola Holdich, Harrison and Bruce, 1981: 569, fig. 6 (part).

Natatolana luticola - Bruce 1981: 958; 1986: 101, fig. 69.

Material examined. ♂, AM P32456, Battery Point, Thursday Island, Queensland, 10°35'S 142°13'E, seagrass beds, P.C. Young, CSIRO, 17 April 1979, BPA Rep. 3 20:15 SP8. ♀ from station NT-156, AM P44853. Series from Melville Bay, Gove, Northern Territory, 12°11.75'S 136°41.28'E, grab, R. Hanley *et al.* - ♂, NTM Cr-011518, 12.9 m, 22 March 1992, D5Wb; ♀, NTM Cr-011519, 12.9 m, 22 March 1992, D5Wa; manca, NTM Cr-011520, 12.9 m, 22 March 1992, D5Wd. Manca, QM 18846, Gulf of Carpentaria, Queensland, 10°58.4'S 138°01.5'E, grab, 49 m, FRV *Southern Surveyor*, 22 November 1991, stn 21; ♀, QM W18847, Shelburne Bay, Queensland, 11°22'S 142°58.2'E, grab, 22 m, FRV *Southern Surveyor*, 30 November 1991, stn 71; ♂, QM W18919, Halifax Bay, Queensland 19°07'S 146°36'E, James Cook University 3 Bays Survey, stn X50.

Distribution. *Natatolana luticola* has previously been recorded from Townsville and Thursday Island, Queensland. This distribution is now expanded to include several other localities in northern Queensland, and also Darwin and Gove, Northern Territory. It is known from depths of 1.9 to 49 m.

Ecology. This species has been collected from sediment samples and in trawls. It was extremely rare in the trap collections from Darwin Harbour, only a single specimen being recorded from off Bleesers Creek, East Arm.

Natatolana taiti sp. nov.
(Figs 5-7)

Type material. HOLOTYPE: ♂, 8.5 mm, NTM Cr-011524. Paratypes: 12 specimens, AM P44854; 11 specimens, NTM Cr-011516; 11 specimens, BMNH 1995.732-741; 11 specimens, USNM 264080; 11 specimens, ZMUC CRU-1714. Type Locality: between North Shell and South Shell Islands, Darwin Harbour, Northern Territory, Australia, 12°29.7'S 130°52.9'E, baited trap, unknown substrate - probably rocks and muddy sand, 7 m, S. Keable, 14-15 July 1993, NT-157.

Additional material. Eight specimens from station NT-123, AM P44855; 5 ♂♂, 8 ♀♀, 2 mancas from station NT-171, AM P44856; 4 ♂♂, 5 ♀♀ from station NT-175, AM P44875; 1 specimen NTM Cr-003280, Channel Island, Darwin, Northern Territory, coral reef flat, LWS, A. J. Bruce, 17 October 1985. Five specimens, AM P44858, Thursday Island, Torres Strait, Queensland, 10°35.33'S 142°13.14'E, baited trap, unknown substrate - probably sediment, 9 m, S. Keable, 31 January 1993, QLD-785. 4 ♀♀, AM P44859, Bet Reef, Torres Strait, Queensland, 10°10.54'S 143°33.54'E, baited trap, unknown substrate, 20 m, S. Keable, 30 January 1993, QLD-784. ♀, NTM Cr-005298, Ashmore Reef, north-eastern Australia, [approximately 10°0.08'S 144°20.47'E], north-west side of north-east reef flat, R. Hanley, 21 April 1987, RH 87-35. Series from Shadwell Reef, Queensland, 11°27.66'S 143°46.63'E, baited trap, unknown substrate, 20-35 m, S. Keable, 12 January 1993, QLD-642, QLD-644, QLD-645; 3 ♀♀, AM P44860; 3♂♂, 3♀♀, 8 mancas, AM P44861; ♀, AM P44862.

Material described. Holotype.

Diagnosis. *Cephalon*: rostral point present. Eyes present. Interocular furrow moderately developed, distinct but not extending from eye to eye. *Frontal lamina*: lateral margins straight, parallel. *Labrum*: without lamina projection. *Antenna*: 0.3 x length of body, reaching to posterior of pereonite 3; flagellum without digitate process on articles. *Coxal plates*: with furrows moderately developed on all coxae; coxa 2 with anteroventral corner not produced into acute tooth. *Pleonite 2*: ventral posterolateral margin acute, not formed into curved process. *Pleonite 3*: posterolateral margins apex acute. *Pleonite 4*: posterolateral margins apex rounded. *Pleotelson*: anterodorsal depression absent; anterolateral margins convex; posterolateral margins convex; apex produced into a small point; approximately four robust setae present. *Pereopod 2*: propodal palm without robust setae. *Pereopod 7*: basis broad; anterior margin sinuate; posterior margin convex. *Penes*: absent. *Pleopod 2 appendix masculina*: subequal with tip of endopod; width slender; margins very slightly curved laterally, parallel along entire length; apex not at angle to margins, bluntly rounded. *Uropods*: exopod slightly shorter than endopod; endopod lateral margin slightly convex; exopod lateral margin convex, robust setae present.

Description. *Male overall body form*: 8.5 mm long; narrow, approximately 3 x as long as wide. Colour translucent white in alcohol. Chromatophores absent.

Cephalon: submarginal cephalic furrow well developed, runs entire length of margin. Eyes present, moderate in size; with nine ocelli in horizontal diameter; with seven ocelli in vertical diameter; round; colour black in alcohol. Interocular furrow moderately developed, distinct but not extending from eye to eye.

Frontal lamina: very elongate, approximately 5 x longer than basal width; lateral margins straight, parallel; anterior apex expanded, forming an acute point.

Antennule: peduncular article 1 longer than article 2; article 2 with one large pappose seta; article 3 long, larger than article 1 or 2 but shorter than their combined lengths. Flagellum shorter than peduncle, 9-articulate; proximal article longest; subsequent articles not alternating in length from short to long.

Antenna: medium length, 0.3 x as long as body; when extended against the body reaching to posterior of pereonite 3. Peduncular article 2 shorter than article 3; article 4 with about three small slender setae at distal angles; article 5 longer than article 4 and all other articles, with two pappose setae at posterodistal angle. Flagellum 22-articulate.

Mandible: incisor with broad, flattened middle tooth; palp article 2 of medium length, approximately twice the length of article 3; setal row with 11 robust setae.

Maxillule: endopod with one small slender seta in addition to the pappose setae; exopod with 13 robust setae on gnathal surface.

Maxilla: palp with four slender setae; endopod with eight slender and six plumose setae; exopod with 13 slender setae.

Maxilliped: palp moderately setose; article 3 length subequal to breadth; article 4 length less than breadth; article 5 length subequal to breadth. Endite with two coupling hooks, two plumose and two slender setae.

Pereon: ornamentation, one strongly developed furrow on lateral margin of pereonite 1; pereonites 1, 5-6 subequal and longest, 2-4 and 7 subequal.

Coxal plates: furrows moderately developed on all coxae. Coxal points variously developed; pereonite 1 and coxae 2-4 with rounded posteroventral margins, coxae 5-7 with increasingly produced, broad, acute posteroventral margins.

Pleonites: ornamentation, one weakly developed furrow on posterolateral margins of pleonites 3 and 4. *Pleonite 2*: dorsal posterolateral margin subequal with ventral posterolateral margin. *Pleonite 4*: posterolateral margins produced posterior to those of pleonite 3; apex rounded.

Pleotelson: length 0.95 x basal width; anterodorsal depression absent; anterolateral margins convex; posterolateral margins convex; apex produced into a small point; robust setae present, four altogether, two on each posterolateral margin; marginal plumose setae present, moderately abundant, on posterolateral margins only.

Pereopods 1-6: without conspicuous elongated robust setae. *Pereopod 1*: basis with slender setae on anterior margin. Ischium anterodistal angle without robust setae but with seven long slender setae; posterior margin without robust setae, slender setae present, sparse. Merus anterodistal angle with one robust seta at apex, one set further back and one row of slender setae; posterior margin slightly sinuate, with eight robust setae, slender setae absent. Merus-carpus with only carpus proportionally shorter than on pereopods 2 and 3. Carpus short, less than half the length of the propodus; with one robust seta and one slender seta present. Propodus longer than on pereopods 2 and 3; with three robust setae on palm, slender setae present on margin. Dactylus short, not as long as propodus; slender. *Pereopods 2-3*: merus and carpus with larger robust setae and carpus with more robust setae than on pereopod 1. *Pereopod 2*: ischium anterodistal angle without robust seta; posterior margin with two robust setae. Merus anterodistal angle with three robust setae; posterior margin with seven robust setae. Carpus with five robust setae. Propodus without robust setae on palm. *Pereopod 3*: ischium anterodistal angle produced but not as strongly as pereopods 1 and 2, with one robust seta; posterior margin with one large and two small robust setae. Merus anterodistal angle with four robust setae; posterior margin with 7 robust setae; robust setae longer than on pereopod 1. Carpus with five robust setae. Propodus without robust setae on palm. *Pereopods 4-6*: becoming progressively longer. *Pereopods 4-7*: progressively decrease in relative amount of robust setae. *Pereopod 4*: propodus with three robust setae on palm; two robust setae opposing dactylus. *Pereopods 5-7*: relative morphology similar but basis of pereopod 5 narrower than on pereopods 6 and 7, ischium and merus of pereopods 5 and 6 distinctly broader and with greater number of robust setae than on pereopod 7. *Pereopod 6*: basis subequal with the width of pereopod 7; propodus longer than that of pereopod 7. *Pereopod 7*: basis broad, width 0.53 x length; anterior margin sinuate, with long plumose setae along entire length; medial carina with short plumose setae along entire length; posterior margin convex, with plumose setae along proximal third only; posterodistal angle with long plumose setae. Ischium anterior margin with sparse slender setae present; anterodistal angle with two robust setae, slender setae present; posterior margin with two robust setae submarginally, plumose setae present; posterodistal angle with one robust seta, one slender seta present. Merus anterodistal angle with four robust setae, slender setae present; posterior margin with five robust setae, slender setae present; posterodistal angle with six robust setae, one slender seta present. Carpus anterior margin with one slender seta present; anterodistal angle with 5 robust setae, slender setae present; posterior margin with three robust setae, one slender seta present; posterodistal angle with five robust setae, slender setae present. Propodus longer than carpus; anterior margin with slender setae present; posterior margin with seven robust setae, slender setae absent; posterodistal angle with three robust setae; anterodistal angle with slender setae present.

Penes: absent, vasa deferentia opening flush to surface of sternite 7.

Pleopods: pleopods 1-2 peduncles with three to four coupling hooks; exopod broader than endopod; pleopod 1 exopod margin rounded; endopod margin narrow at apex. *Pleopod 2 appendix masculina*: arising sub-basally; subequal with tip of endopod; 0.99 x length of endopod; margins very slightly curved laterally, approximately parallel along entire length; apex not at an angle to margins, bluntly rounded. *Pleopods 3-5*: exopod suture present (but extremely faint).

Uropods: extending beyond pleotelson; peduncle ventrolateral angle with two robust setae. Endopod lanceolate; medial margin convex, with four robust setae, long plumose setae present along entire length; apex with two robust setae;

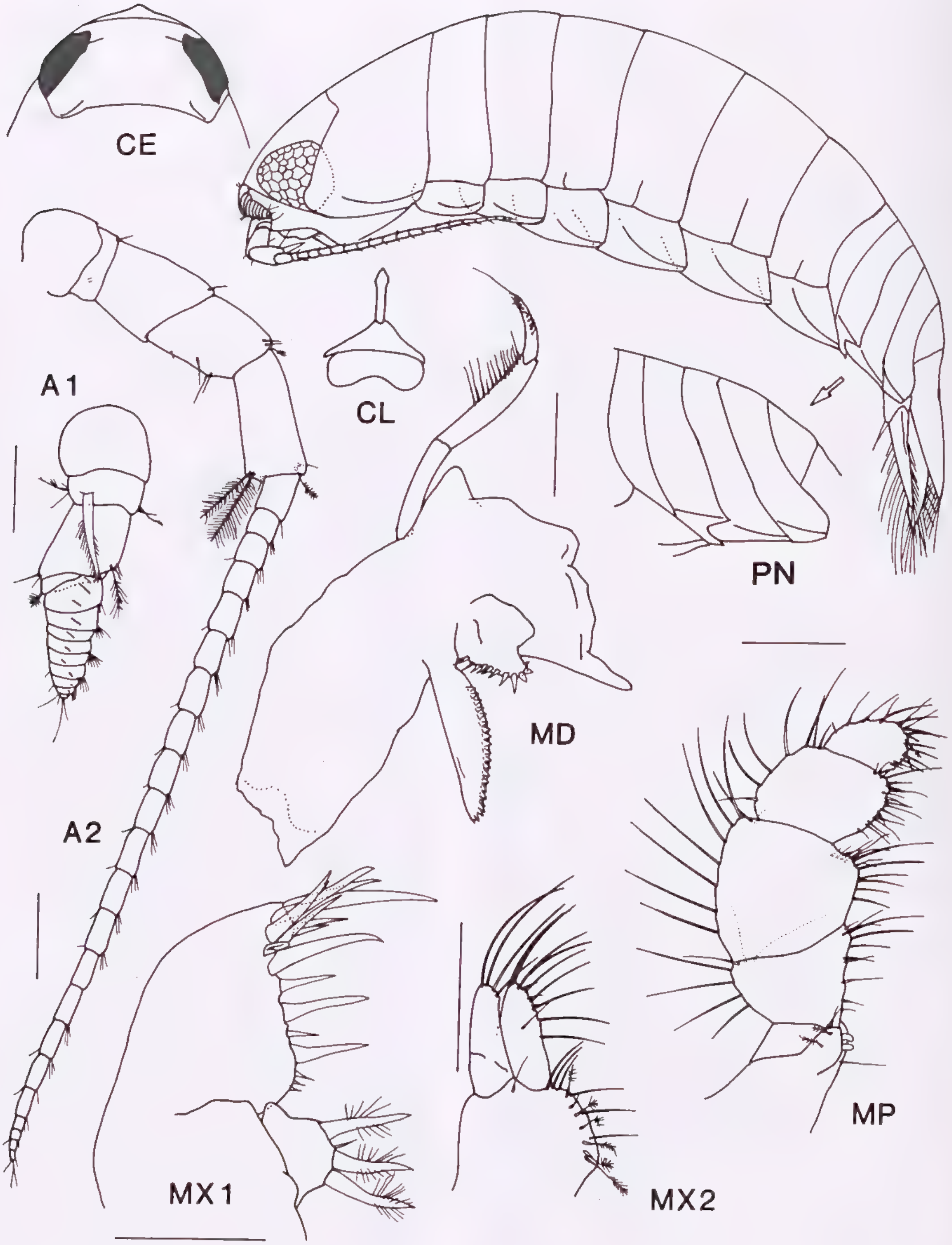

Fig. 5. *Natatolana taiti* sp. nov., holotype. Scales = 0.2 mm.

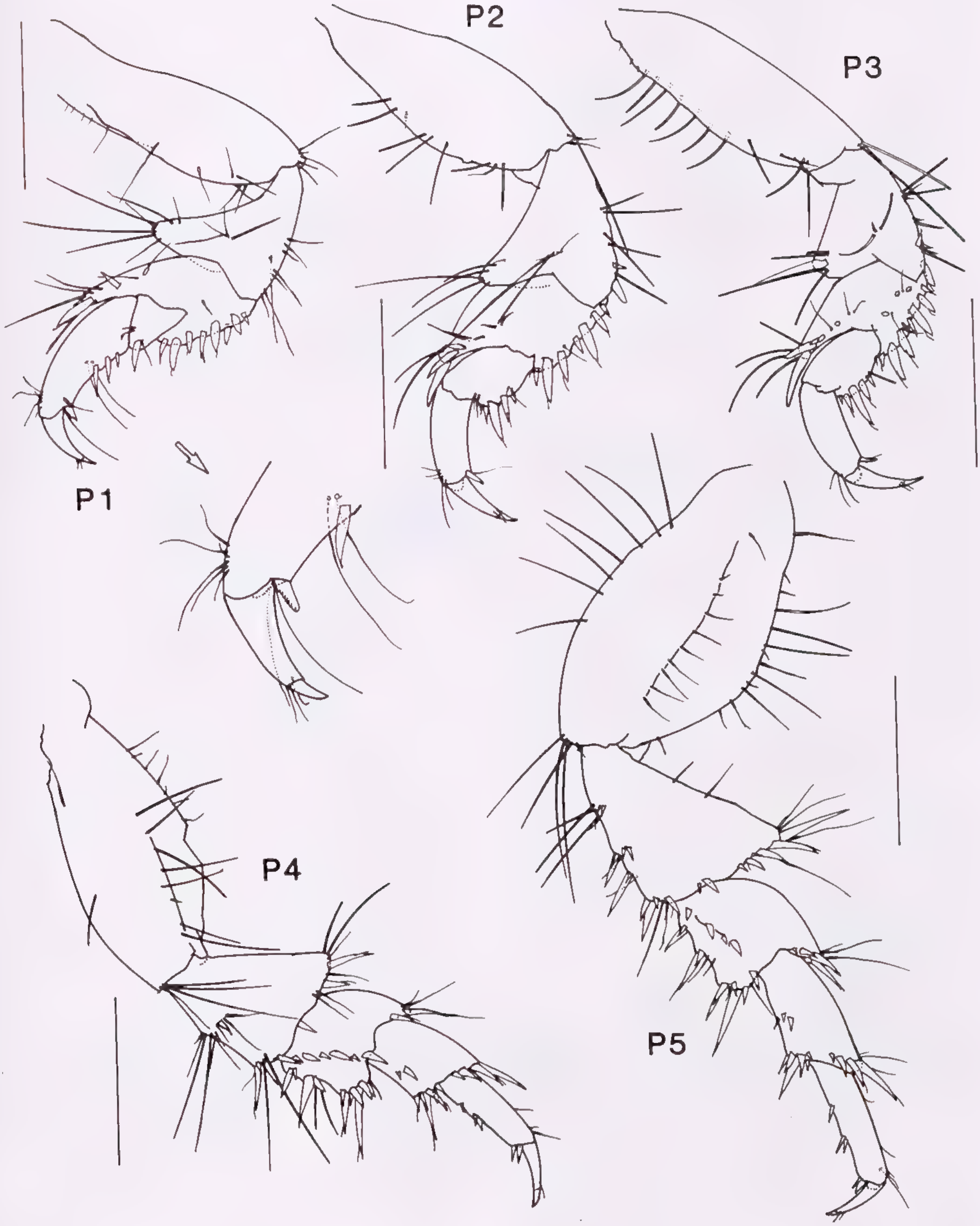

Fig. 6. *Natatolana taiti* sp. nov., holotype. Scales = 0.5 mm.

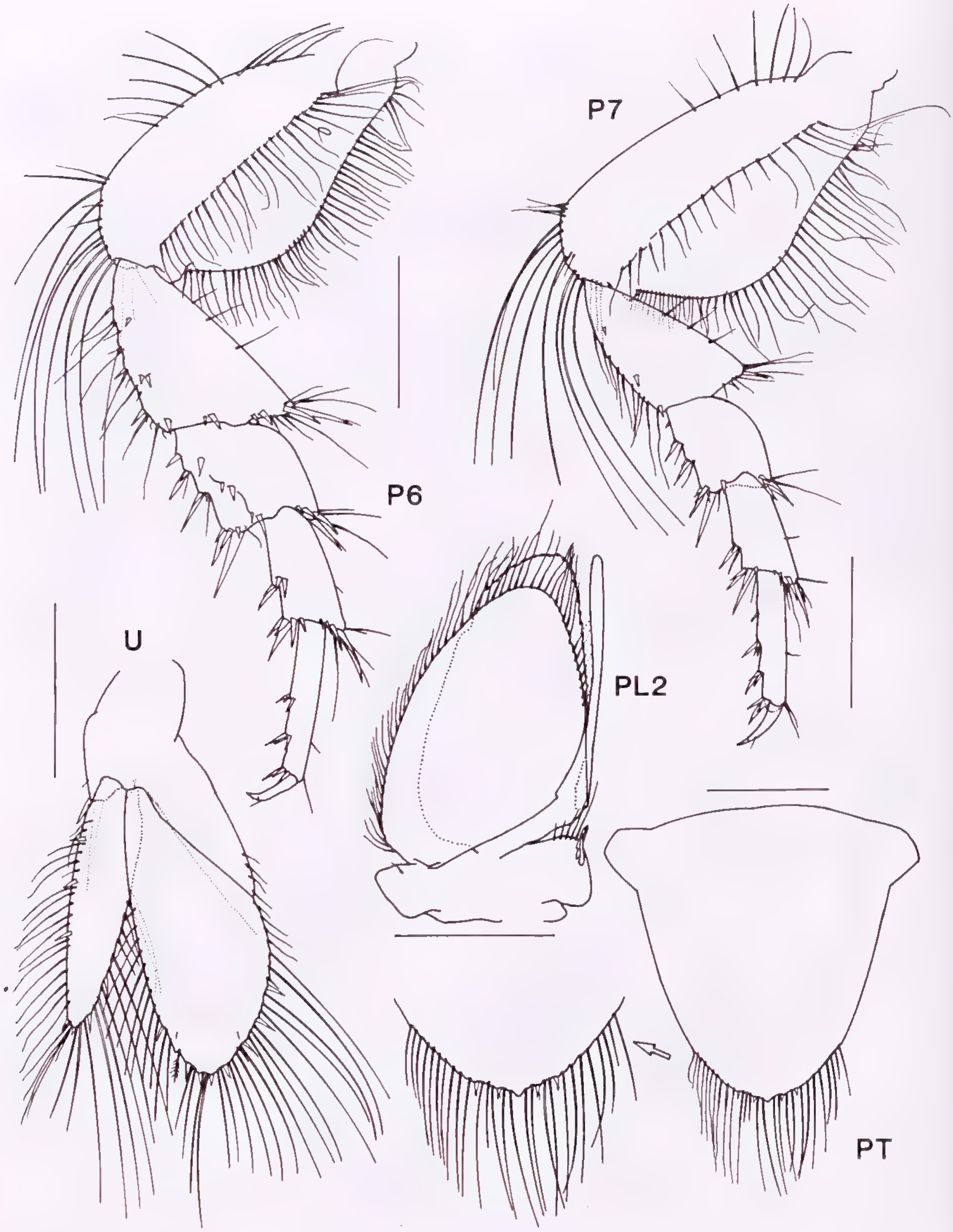

Fig. 7. *Natatolana taiti* sp. nov., holotype. Scales = 0.5 mm.

lateral margin slightly convex, with two robust setae, short plumose setae present on distal two thirds. Exopod slightly shorter than endopod, 0.79 x length; medial margin convex, with two robust setae, very long plumose setae present on entire length; apex acute, with 2 robust setae; lateral margin convex, with 3 robust setae, plumose setae present on entire length.

Sexual dimorphism. Females differ from males only in the primary sexual characters.

Variation. The 57 paratype specimens were examined for variation in the number of robust setae on the pleotelson margins. Ten were damaged and omitted from consideration, of the remainder 85% have four robust setae, 2% have three, 4% have five and 9% have six. In the material from Shadwell Reef, Queensland, most of the adult specimens have six robust setae on the pleotelson.

Size range. Up to approximately 12 mm.

Remarks. *Natatolana taiti* is similar to both *N. woodjonesi* (Hale, 1924) and *N. kahiba* Bruce, 1986. It differs from adult specimens of these species in having longer antennae, reaching to the posterior of pereonite 3 and 0.3 x as long as the body when extended along it (reaching to the posterior of pereonite 2 with 18-21 articles in the flagellum and 0.25 x as long as the body in *N. woodjonesi*; reaching to the posterior of pereonite 2, with approximately 12 - 18 articles and 0.25 x as long as the body in *N. kahiba*). Other differences include the less acute posterior margins of the pleotelson and uropod endopod apex in *N. taiti*. Additionally, there is an error in the key provided by Bruce (1986) - the species *N. arrama* Bruce, 1986 and *N. bulba* Bruce, 1986 (which are described as having four robust setae on the pleotelson) can only be reached if it is assumed in couplet 21 that they have six or more robust setae. These two species are also similar to *N. taiti*. *Natatolana arrama* differs in having a frontal lamina with the apex not expanded; the antennae with approximately 18 articles in the flagellum, reaching to the middle of pereonite 2, 0.24 x the length of the body; the uropod exopod lateral margin lacking robust setae and the endopod narrower and more lanceolate; also the posterolateral margins of the pleotelson are less convex. *Natatolana bulba* is very similar but differs in having a narrower, more lanceolate uropod endopod and lacking robust setae on the uropod exopod lateral margins, also the posterolateral margins of the pleotelson are less convex.

Distribution. This species is known from Darwin, Northern Territory; Ashmore Reef, north-eastern Australia; far northern Queensland; in depths of 5 to 35 m.

Ecology. *Natatolana taiti* was a common and widely distributed scavenger throughout Darwin Harbour, and also occurred between Nightcliff and East Point. It was most abundant among shallow subtidal mudflats and comparatively rare in the channels where gravel and terrigenous sand predominate.

Etymology. This species is named after Dr Noel Tait (Macquarie University), in recognition of the help he has given me during this study and in a number of other investigations.

Natatolana tenuistylis (Miers, 1884)

Cirolana tenuistylis Miers, 1884: 303, pl. 33B. - Holdich, Harrison and Bruce 1981: 572, fig. 7.

Natatolana tenuistylis - Bruce 1986: 103, figs 70, 71.

Material examined. CSIRO North-west Shelf series 1983, S=sled, BT=beam trawl - AM P44863-44864, ♂ (immature), 19°29.6'S 118°52.5'E, 40 m, 05-D3-BT; ♀, 19°55.9'S 117°55.8'E, 42 m, 02-B3-S. Darwin, Northern Territory, baited trap series - 2 ♀♀ from station NT-123, AM P44865; 12 ♂♂, 20 ♀♀ from station NT-146, AM P44866; 82 specimens from station NT-188, AM P44867. 3 ♂♂, 3 ♀♀, 13 mancas, NTM Cr-00283, Oxley Island, Northern Territory, 10°59.0'S 132°48.8'E. 2 ♂♂, 3 ♀♀, QM W18906, Daru Island, Papua New Guinea, 9°05'S 143°10'E, from nasal tract of dugong, Papua New Guinea Wildlife Department. FRV *Southern Surveyor* Gulf of Carpentaria, Queensland Series - 2 ♀♀ (1 ovigerous), QM W18878, 13°29.2'S 140°12'E, 62 m, stn 46, 30 November 1990; ♀, QM W18887, 13°58'S 140°41'E; ♀, QM W18891, 15°26.8'S 138°12'E, 43.5 m, stn 18, 25 November 1990; ♂, ♀, QM W18881, 14°28.8'S 140°11.5'E, 59 m, stn 44, 30 November 1990; ♀, QM W18882, 10°30.2'S 141°09.7'E, grab, 23 m, stn 57, 03 December 1990; 5♂♂, ♀, 3 mancas, QM W18889, 10°58.55'S 141°12'E, grab, 31 m, 03 December 1990, stn 56; ♂, QM W18885, 14°57.7'S 139°42'E, grab, 54 m, 07 December 1990, stn 74. ♂, 6 mancas, AM P44871, Thursday Island, Torres Strait, Queensland, 10°35.33'S 142°13.14'E, baited trap, unknown substrate - probably sediment, 9 m, S. Keable, 31 January 1993, QLD-785. Several hundred specimens, AM P44868, Bet Reef, Torres Strait, Queensland, 10°10.54'S 143°33.54'E, baited trap, unknown substrate, 20 m, S. Keable, 30 January 1993, QLD-784; ♂, QM W18927, Shelburne Bay, Queensland, dredged, CSIRO Cruise 0192 stn 94; ♀, QM W18844, Shelburne Bay, Queensland, grab, 21 m, 30 November 1991, stn 70; 2 ♀♀, manca, QM W18890, 13°30'S 140°42'E; 108 specimens, AM P44869, off reef at North

Point, Lizard Island, Queensland, 14°40'S 145°28'E, baited trap, on sandy bottom, 22 m, S. Keable and D. Townsend, 9-10 June 1989; 70 specimens, AM P44870, off reef at Base of Chinamans Ridge, Lizard Island, Queensland, 14°40'S 145°28'E, baited trap, on fine flat sand, 9 m, S. Keable and D. Townsend, 15-16 June 1989.

Remarks. This species was redescribed by Holdich *et al.* (1981) and a lectotype designated. The lectotype was described as having four robust setae present on one side of the pleotelson apex, although there may have been more originally. Because the robust setae on the pleotelson are usually paired (Bruce 1993: 11) this suggests that the usual number of robust setae present in this species could be expected to be eight or more. The lectotype was also described as having penes present as two minute, widely separate papillae. The lectotype description was supplemented by Bruce (1986) who described a male from North Molle Island, Queensland, which has 10 robust setae on the pleotelson. Bruce (1986) also noted that useful characters in identifying this species are the presence of a complete interocular furrow, the ventral posterolateral margin of pleonite 2 which is produced and formed into an acute process, and the acute projection on the apex of the appendix masculina.

In the material examined here the majority of specimens have eight robust setae on the pleotelson. However, specimens with 10 are also common and in the larger samples specimens with either number are usually present. Occasional specimens have nine, 11 or 12 robust setae on the pleotelson. Thirty specimens in AM P44868 from Bet Reef, Torres Strait (very close to the type locality of Prince of Wales Channel) were also examined for variation in the number of robust setae on the pleotelson. In this subsample 53% of these specimens had eight robust setae, 30% had nine and 17% had 10.

Male specimens have the openings of the vas deferens so slightly raised that they are indistinguishable from those of species described as having the vas deferens opening flush to the surface of the sternite.

One female specimen from Shelburne Bay, Queensland, (QM W18844) has unusually long antennal flagella which reach to the posterior of pereonite 7 and are composed of 30 articles. However, this specimen is otherwise indistinguishable from the others.

In juvenile specimens the ventral process on the lateral margins of pleonite 2 are not as produced as in adults and immature male specimens have a bluntly rounded apex on the appendix masculina. Other characters which were found to be useful in identifying this species are; the long antennae which usually reach to the posterior of pereonite 5 and are approximately 0.6 x the length of the body, and the unusual shape of the lateral margin of pleonite 4 which is rounded dorsally and meets the ventral margin at a point (as illustrated by Bruce (1986)).

Distribution. *Natatolana tenuistylis* has previously been recorded from Torres Strait and North Molle Island, Queensland. This distribution is now expanded to include north-western Australia, the Northern Territory, much of northern Queensland, and also Daru, southern Papua New Guinea. This species occurs in depths of 3 to 62 m.

Ecology. *Natatolana tenuistylis* is a scavenger and was widely distributed throughout Darwin Harbour, occurring in shallow embayments and in the scour zone of the channels. It was particularly abundant and usually the numerically dominant species in trap samples from shallow subtidal mudflats and terrigenous sands. It was absent or extremely rare near rock or coral reef habitats, as is the case at Lizard Island, Queensland (Keable 1992, 1995).

Natatolana thalme Bruce, 1986

Natatolana thalme Bruce, 1986: 113, figs 79, 80.

Material examined. Fifteen paratypes, AM P32382, Middle Banks, Moreton Bay, Queensland, 27°06'S 153°16'E, S. Cook and S. Newlands, December 1973. CSIRO North-west Shelf series 1983, AM P44872-44876, S=sled - ♀, 19°29.7'S 118°52.5'E, 39 m, L036-05-D2-S; ♂,♀, 19°30.5'S 118°49.5'E, ALPHA 843-05-B7-S; ♂, 3 ♀♀, 19°56.9'S 117°53.7'E, 42-43 m, O150-02-B2-S; ♂, 19°59.0'S 117°51.4'E, 42 m, U840-01-B1-S; ♂ (poor condition), ♀, 19°05.0'S 118°57.8'E, 83-82 m, O295-02-B10-S. Darwin, Northern Territory, baited trap series - 25 specimens from station NT-180, AM P44877; ♂ from station NT-130, AM P44878; 6 ♂♂, 17 ♀♀ from station NT-132, AM P44879. 3 ♀♀, manca, AM P44880, 400 m off Shadwell Reef, Queensland, 11°27.6'S 143°46.6'E, baited trap, unknown substrate, 25 m, S. Keable, 12 January 1993. Series of 9♂♂, 29♀♀, manca, AM P44881-

44885 and P40177, Lizard Island, Queensland, 14°40.0'S 145°28.0'E, baited trap, sediments, 0-5 m, S. Keable *et al*., 1989-90. Seven topotype specimens, QM W14250, Middle Banks, Moreton Bay, Queensland.

Remarks. Occasional specimens (AM P40177, AM P44873, AM P44874, AM P44878, AM P44884) have six robust setae on the margins of the pleotelson but the majority of specimens from the same localities have four as described by Bruce (1986).

Distribution. *Natatolana thalme* was previously known only from Lizard Island and Moreton Bay, Queensland. This distribution is now expanded to include localities in northern Queensland, the Northern Territory and northwestern Australia. It occurs in depths of 0 to 83 m.

Ecology. This species is a scavenger. Within Darwin Harbour it was collected only in the immediate vicinity of Fannie Bay. However, it was common in trap samples from off Rapid Creek to the north-east of Darwin. This distribution corresponds to the distribution of calcareous sand and gravel sediment in the vicinity of Darwin Harbour.

Natatolana variguberna (Holdich, Harrison and Bruce, 1981)

Cirolana variguberna Holdich, Harrison and Bruce, 1981: 566, fig. 5.

Natatolana variguberna - Bruce 1986: 105, fig. 72; 1995: 409, fig. 19A-E.

Material examined. 270 specimens, AM P44886, off Padoz Natun, Madang Lagoon, Papua New Guinea, 5°09.60'S 145°49.77'E, baited trap on soft mud, 35 m, J. Lowry and S. Keable, 17-18 March 1991, PNG-254. 32 specimens from station NT-119, AM P44887; 48 specimens from station NT-148, AM P44888. Ovigerous ♀, ZMUC CRU-119, Arafura Sea, 10°43'S 139°17'E, 54 m, RV *Galathea*, 27 September 1951, stn. 502. Series of 5 ♂♂, 9 ♀♀, 3 mancas, QM W18871, W18877, W20572, W18850, W18853, W18859, W18860, W18863, W18864, W18868, W18873, W18866, W18874, W18875, W18876, W18879, Gulf of Carpentaria, between 10°12.8'-15°01.3'S 136°19'-140°41.9'E, grab, 17-63 m, FRV *Southern Surveyor*, 1990-91. ♂ (damaged), QM W18845, Shelburne Bay, Queensland, 11°22'S 142°55.6'E, 21 m, FRV *Southern Surveyor*, stn 72, 1 December 1991. Series of 2 ♂♂, 30 ♀♀, 3 mancas, AM P44889-44895 and P44921-44932, Lizard Island, Queensland, 14°40'S 145°28'E, baited trap, sediments, 3-25 m, S. Keable *et al*., 1989-90. Topotype series Halifax Bay, Queensland, 19°07'S 146°36'E, James Cook University 3 Bays Survey - 1 specimen, QM W18921, stn V42, 24 Feb. 1977; ♀ (ovigerous), QM W18925, stn Q311A; ♀ (damaged), QM W18926, stn Q238A.

Remarks. Bruce (1986) stated that this species presents a constant form throughout its range. The species was originally described as having six robust setae on the pleotelson margin. In the Material Examined above, this was the case for the majority of specimens from Papua New Guinea and the Gulf of Carpentaria, although a few specimens from both of these localities have only four robust setae on the pleotelson. However, in the material from Darwin and Lizard Island the majority of specimens have four robust setae on the pleotelson and only occasional specimens have six. A topotype female from QM W18925 also has four robust setae. Therefore, it appears that morphological variation of four to six robust setae on the pleotelson is within the normal range for this species.

There also appears to be a small amount of sexual dimorphism in this species. A number of females have slightly shorter antennae which extend to the posterior of pereonite 3 whereas in males they extend to the posterior of pereonite 5 (described as the level of pereonite 5 by Holdich *et al*. (1981)). This extra length of the antennae is achieved by a lengthening of the articles in the male flagellum rather than an increase in the number of articles present.

One specimen (ZMUC CRU-119) was examined which has both male and female characteristics. This specimen is 9 mm long, it is ovigerous with well developed oostegites holding approximately 10 ova ventrally between pereopods 3-6. The antennae extend to half way along pereonite 4. Medially on sternite 7 there are a pair of modified processes. These resemble the flattened penes of other species of *Natatolana*, eg. *N. bowmani* Bruce and *N. pellucida* (Tattersall) as illustrated by Bruce (1986), except that there are short slender setae around the margins of these processes and it is unclear if the processes are connected to vas deferentia. Penes are considered to be absent in male *N. variguberna* as they have the vas deferentia opening flush with the surface of sternite 7 (Holdich *et al*. 1981).

On the endopod of pleopod 2 of this specimen there is also a well developed appendix masculina which is slightly shorter than that of *N. variguberna* as illustrated by Holdich *et al.* (1981).

The only comprehensive information available on the life history of species of *Natatolana* is provided by Wong and Moore (1996) and Johnasen (1996). They do not record hermaphrodites. Holdich *et al.* (1981), Bruce (1986) and Bruce (1995) examined a number of specimens of *N. variguberna*, including ovigerous females, non-ovigerous females and males. They did not record any specimens with characteristics of both sexes. None of the other ovigerous females (QM W18860, W18876, W18879, W18925) or other specimens examined in the present study were similar to that described above. Therefore, it appears that this specimen represents a damaged or mutant individual, rather than indicating that a form of hermaphroditism may routinely occur in populations of this species.

Other variations included one specimen from Lizard Island (AM P44891) which has one robust seta on the palm of pereopod 2, whereas in other material this seta is absent.

Distribution. *Natatolana variguberna* has previously been recorded from the Cobourg Peninsula, Northern Territory; Thursday Island, Lizard Island, Townsville and Moreton Bay, Queensland; Madang Lagoon, Papua New Guinea; in depths of 2.7 to 63 m.

Ecology. This species is a scavenger and was widely distributed throughout Darwin Harbour, from the harbour mouth to the upper reaches of all arms. It was particularly abundant in trap samples from shallow mudflats in embayments such as those in Woods Inlet, the upper reaches of West Arm and off Bleesers Creek. It also occurred in the scour zone of the main channels, where gravel sediments predominate, but was not as abundant here as elsewhere.

Genus *Plakolana* Bruce, 1993

Plakolana Bruce, 1993: 9.

Plakolana mandorah sp. nov.
(Figs 8-10)

Type material. HOLOTYPE: ♂, 13 mm, NTM Cr-011525. Paratypes: 10 specimens, AM P44933; 10 specimens, NTM Cr-011517; 10 specimens, BMNH 1995.722-731; 10 specimens, USNM 264081; 10 specimens, ZMUC CRU-1715. Type locality: just off West Point on transect toward East Point, Darwin Harbour, Australia, 12°26.3'S 129°46.3'E, baited trap, unknown substrate - probably rocky reef, 8 m, S. Keable, 8-9 July 1993, NT-123.

Additional material. Twenty four specimens from station NT-146, AM P44934; 9 ♂♂, 26 ♀♀, 2 mancas from station NT-171, AM P44935. ♀, manca, AM P44936, Bet Reef, Torres Strait, Queensland, 10°10.54'S 143°33.54'E, baited trap, unknown substrate, 20 m, S. Keable, 30-31 January 1993, QLD-784.

Material described. Holotype.

Diagnosis. *Antenna*: reaching to the posterior of pereonite 4. *Uropods*. endopod distally narrowed; robust setae short, 8% length of endopod; medial margin convex; apex with subequal robust setae; lateral margin straight medially, slightly convex toward apex.

Description. *Male. Overall body form*: 13 mm long; narrow, approximately 3.2 x as long as wide. Colour translucent white in life and alcohol. Chromatophores absent.

Cephalon: submarginal cephalic furrow well developed, runs entire length of margin. Eyes present, well developed; moderate in size; with approximately 10 ocelli in horizontal diameter; with eight ocelli in vertical diameter; ovate; colour red-brown in alcohol. Interocular furrow well developed, extending from eye to eye.

Frontal lamina: about 6 x longer than the basal width; lateral margins straight, narrowing anteriorly; anterior apex expanded, formed into an oval (but appears to be aberrant).

Antennule: peduncular article 3 long, larger than article 1 or 2 but shorter than their combined lengths; antennule short, not reaching pereonite 1. Flagellum 13-articulate; article 1 longest; aesthetascs present.

Antenna: 0.4 x as long as body; when extended against the body reaching to the posterior of pereonite 4. Flagellum 35-articulate.

Mandible: palp, article 2 with approximately 17 slender and four biserrate setae; setal row with 10 robust setae; molar with approximately 22 robust setae on margin and three long slender setae.

Maxillule: endopod with three robust, pappose setae; exopod with 12 robust setae on gnathal surface, one of which is relatively narrow and uniserrate.

Maxilla. Palp with five slender setae; endopod with 10 plumose and five slender setae; exopod with eight slender setae.

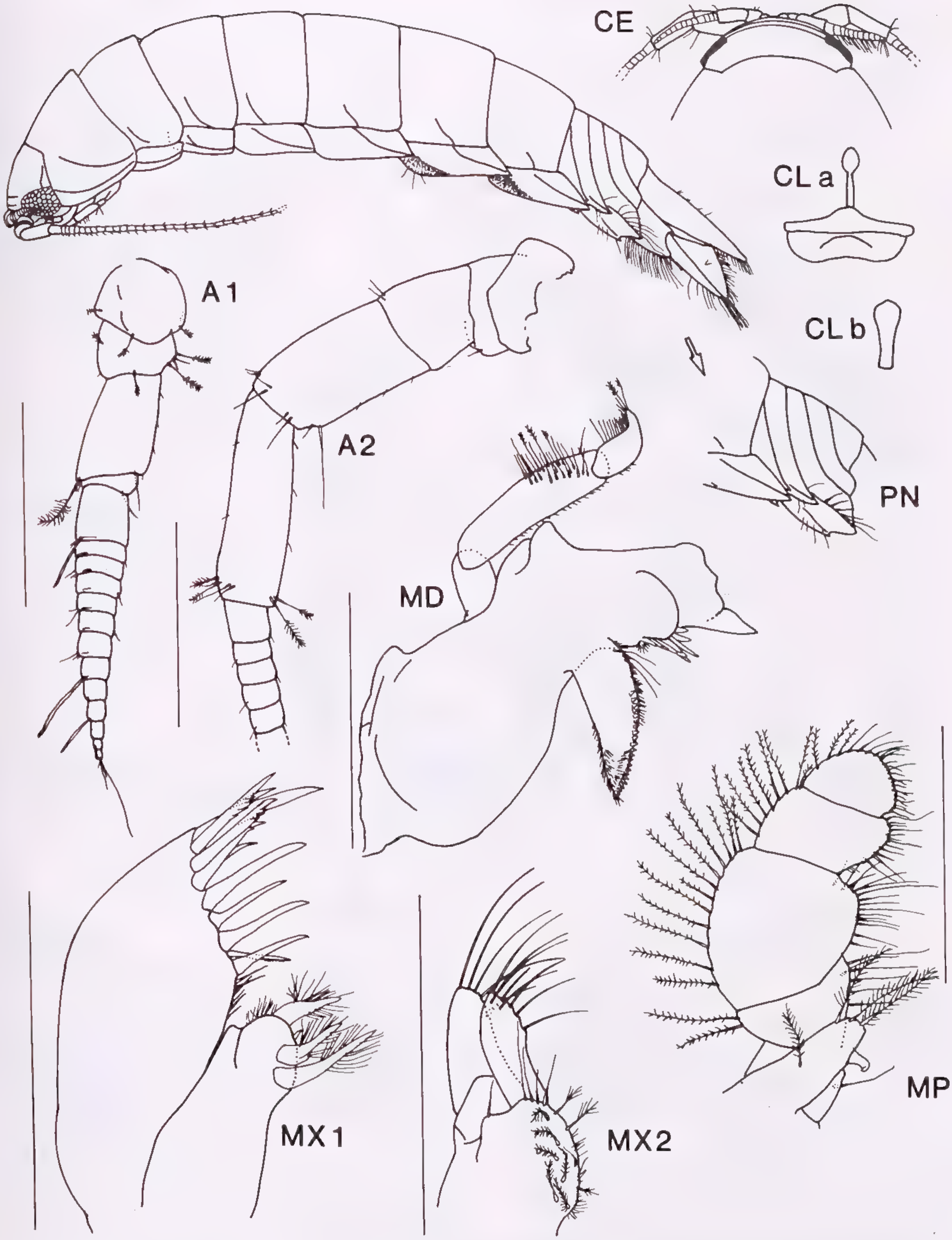

Fig. 8. *Plakolana mandorah* sp. nov., holotype except CLb = frontal lamina of paratype ♀ AM P44933. Scales = 0.5 mm.

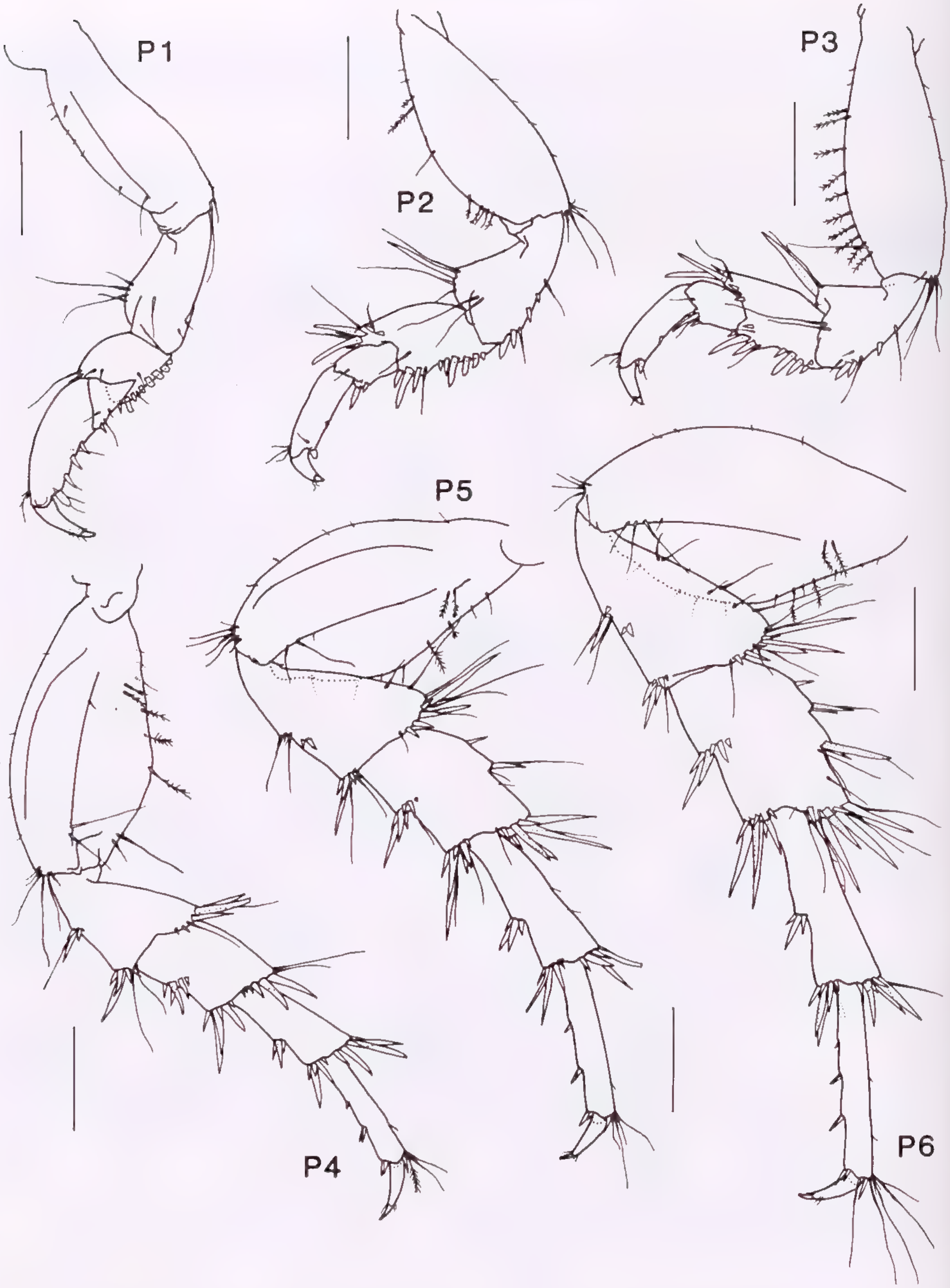

Fig. 9. *Plakolana mandorah* sp. nov., holotype. Scales = 0.5 mm.

Maxilliped: palp moderately setose, setae on lateral margin all plumose; endite with one coupling hook and four plumose setae.

Pereon: pereonites 1, 5-7 subequal in length and longer than 2-4 which are subequal.

Pleonites: pleonite 1 completely concealed in dorsal view by pereonite 7, pleonite 2 partially concealed, pleon approximately 0.14 x body length.

Pleotelson: basal width approximately equal to length; anterolateral margins convex;

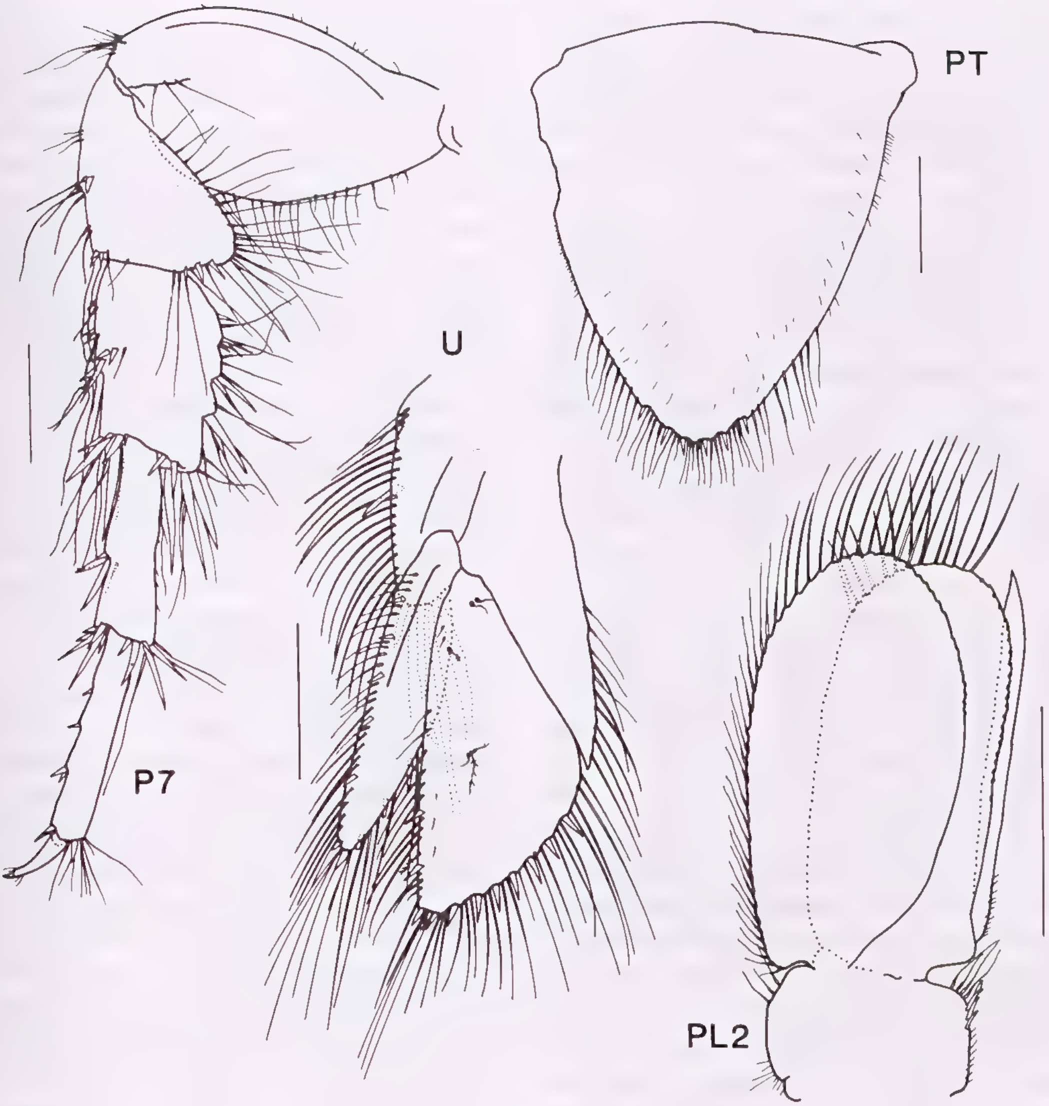

Fig. 10. *Plakolana mandorah* sp. nov., holotype. Scales = 0.5 mm.

posterolateral margins convex; apex not produced, lateral margins meeting smoothly to a point; robust setae present, six altogether, three on each posterolateral margin; marginal plumose setae present, moderately abundant, on posterolateral margins only.

Pereopods 1: basis with sparse short slender setae on anterior margin; posterodistal angle with two slender setae. Ischium anterodistal angle with four slender setae; posterior margin with two small, slender setae. Merus anterodistal angle with two slender setae at apex, two short, slender setae set further back; posterior margin with eight robust setae and two short slender setae. Carpus with one robust seta, three slender setae present. Propodus with three robust setae on palm, one robust seta opposing dactylus, marginal slender setae present; anterodistal angle with one row of small slender setae. *Pereopod 2*: ischium anterodistal angle with one robust seta; posterior margin with four robust setae and two slender setae. Merus anterodistal angle with four robust setae at apex and two more set further back; posterior margin with nine robust setae. Carpus with three robust setae. Propodus with one robust seta on palm; 1 robust seta opposing dactylus. *Pereopod 7*: basis anterior margin convex, with plumose setae along entire margin; posterior margin convex, without setae; posterodistal angle with one group of slender setae. Ischium anterior margin with plumose setae along most of length; anterodistal angle with three robust setae; posterior margin with two robust setae and patches of short slender setae mixed with longer plumose setae; posterodistal angle with three robust setae. Merus anterior margin with eight robust setae, slender setae and plumose setae; anterodistal angle with five robust setae; posterior margin with eight robust setae, short slender setae and longer plumose setae; posterodistal angle with five robust setae. Carpus anterodistal angle with five robust setae; posterior margin with four robust setae and one slender seta; posterodistal angle with seven robust setae. Propodus with one robust seta and several slender setae at anterodistal angle; posterior margin with four robust setae; two robust setae at posterodistal angle.

Penes: absent, vasa deferentia opening flush to surface of sternite 7.

Pleopods 2 appendix masculina: arising sub-basally; extending subequal with tip of endopod; margins straight, approximately parallel along entire length; apex not at an angle to margins, acute. *Pleopods 3-5*: exopod suture feebly developed.

Uropods: peduncle lateral margin with one robust seta, plumose setae along entire length; posterodistal angle with two robust setae and several plumose setae. Endopod medial margin convex with seven robust setae, plumose setae present along entire length; apex with two robust setae; lateral margin straight medially, slightly convex toward apex, with two robust setae and one penicillate seta, plumose setae present on distal half. Exopod slightly shorter than endopod, 0.88 x endopod length; medial margin with four robust setae, plumose setae present; apex acute with two robust setae; lateral margin with five robust setae, plumose setae present along entire length.

Sexual dimorphism. Females differ from males only in the primary sexual characters.

Variation. The frontal lamina of the holotype specimen appears to be damaged or aberrant. In paratype specimens the frontal lamina is approximately four times as long as the basal width, the lateral margins are concave, the apex is expanded and blunt with an angled anterior margin (as shown in Fig. 8). Some paratype specimens have six robust setae on the uropod exopod posterolateral margin. The female specimen from Bet Reef has seven robust setae on the uropod exopod lateral margin and the manca has eight robust setae on pleotelson. A specimen from AM P44934 was also dissected and has two coupling hooks on the endite of the maxilliped.

Size range. Up to 13 mm.

Remarks. *Plakolana mandorah* differs from other species in the genus in having relatively short robust setae on the uropod endopod and a uropod endopod which is distally narrowed with the medial margin convex. The species is closest to *P. accola* Bruce, 1993. It differs from this species in having relatively short robust setae on the uropod endopod (approximately 8% of the length of the endopod lateral margins as opposed to 18%) and uropod endopod lateral margins which are straight or weakly convex rather than weakly sinuate. *Plakolana mandorah* also has more setose anterior margins of the merus and ischium of pereopod 7 than *P. accola* and the maxilliped palp has plumose setae on the lateral margin which are not figured or described for other species of *Plakolana*.

Distribution. *Plakolana mandorah* is known only from Darwin Harbour, Northern Territory and Torres Strait, Queensland, in depths of 8 to 20 m.

Ecology. This species is a scavenger and was one of the numerically dominant taxa from the scour zone of the main channels within Darwin Harbour, where gravel sediments predominate. It was common from the harbour mouth to Shell Islands, East Arm and Channel Island, Middle Arm.

Etymology. This species is named after Mandorah, Darwin Harbour, venue for the Sixth International Marine Biological Workshop and very close to the type locality.

Genus *Pseudolana* Bruce, 1979

Pseudolana Bruce, 1979: 112. - Bruce 1986: 43.

Pseudolana menartae Bruce, 1986

Pseudolana menartae Bruce, 1986: 50, figs 31, 32.

Pseudolana menertae Bruce, 1986: 43, 51, 52, 237, 238 [*lapsus calami*].

Material examined. 2 ♂♂, 3 ♀♀ from station NT-152, AM P44937; several hundred specimens from station NT-180, AM P44938; ♀, NTM Cr-000358, Casuarina Beach, Darwin, Northern Territory, sand, MTL, N.L. Bruce, 21 December 1982.

Remarks. The specimens examined differ very slightly from the original description in having minute coxal points on the posteroventral margins of coxae 2-3 rather than rectangular margins and having six robust setae on the pleotelson margin rather than four. Four of the robust setae occurring on the pleotelson are closely spaced near the apex of the pleotelson as illustrated by Bruce (1986), the other robust setae are more widely separated from these toward the lateral margins.

Distribution. *Pseudolana menartae* is known only from the Cobourg Peninsula and Darwin, Northern Territory and is restricted to the intertidal zone.

Ecology. This species is a scavenger and was collected in low numbers in trap samples from beach sediments in the lower reaches of the harbour. It was exceptionally abundant in trap samples set in the intertidal zone off Casuarina Beach, to the north-east of Darwin.

DISCUSSION

Twenty two species were collected using baited traps and an additional two species from Darwin were located in museum collections. *Cirolana stenoura* Bruce, 1986 and *Neocirolana excisa* (Richardson, 1910) previously recorded from Darwin (Bruce 1986, 1994) were not collected, therefore 26 species in nine genera are now known from this locality.

In making comparisons between the diversity of this fauna with that of other areas, it should be noted that an important factor to consider is the collection methods used. Holdich *et al.* (1981) indicated that cirolanids may be able to avoid some collection methods. The large number of species reported here which do not seem to have been collected in abundance, other than by using baited traps, supports this view. Of the areas where extensive trap collections have been made, the diversity of the cirolanid fauna of Darwin Harbour is very similar to that of Madang Lagoon, Papua New Guinea (27 species, 11 genera, Bruce (1993)). It exceeds that of Lizard Island, Queensland, (17 species, seven genera, Bruce (1986), Keable (1995), personal observation), Heron Island, Queensland, (16 species, seven genera, Bruce (1986, 1993)) and Port Jackson, New South Wales, (15 species, five genera, Bruce (1986), Keable (unpublished data)).

A further factor to consider when comparing the cirolanids present in different localities is the habitats occurring there. The diversity of members of the scavenging guild, including cirolanid isopods, may reflect the diversity of habitats present (Keable 1995). In Darwin Harbour the extreme tidal ranges create an array of dynamic sedimentary habitats subtidally, the high turbidity also results in the presence of a restricted coral fauna (Michie 1988). Under these conditions the majority of subtidal species found occurred among sediments. The genus *Natatolana,* which contains species primarily adapted for burrowing in sediments (Wägele and Bruce 1989), was noticeably diverse in Darwin Harbour with seven species present. In contrast, in Madang Lagoon, Papua New Guinea, sediments are less variable and there are only two species of *Natatolana* present. One of these is an atypical reef inhabiting species and most of the other cirolanids found there are also from coral reef habitats (N. Bruce *in litteris*).

The diversity of cirolanids collected from Madang Lagoon was considered high by Bruce (1993). The cirolanid fauna of Darwin Harbour is composed of a similar number of species and genera to that of Madang Lagoon. However, the two areas are not directly comparable because of the differences in habitat composition as outlined above and because habitats from continental shelf waters which were sampled by Bruce (1993) in Madang Lagoon are not present in Darwin. Also, extensive collecting using methods other than baited traps is likely to raise the number of species known from Darwin Harbour. This is because ubiquitous genera such as *Eurydice* and *Metacirolana*, which do not feed as scavengers and are not collected in baited traps (Bruce 1986: 6) are yet to be collected there.

Taking these factors into consideration, the results of this study indicate that the cirolanid isopod fauna of Darwin Harbour is rich and diverse. These results also support the suggestion of Bruce (1986) that cirolanid isopods are more diverse in tropical rather than temperate Australia.

Of the species recorded from Darwin (excluding the two species of *Aatolana* which have doubtful distribution records) at least 14 (58%) also occur in Torres Strait and on the north-eastern coast of Australia. The cirolanid fauna of other nearby areas such as Western Australia and Papua New Guinea is much more poorly known. However, at least seven of these species also occur on the west coast of Australia and at least four species have also been collected in Papua New Guinea.

Information from this study also gives a general picture of the distribution of the cirolanid isopod component of the scavenging guild within Darwin Harbour. In the scour zone of the main channels where gravel sediments are prevalent the species *Aatolana ?rapax* and *Plakolana mandorah* are usually the numerically dominant scavengers. In these areas the species *Natatolana tenuistylis*, *N. angula*, *Cirolana capricornica*, *C. mekista*, *Cirolana* sp. 1, *Cirolana* sp. 2 and *Cirolana* sp. 8 may also be common. In the shallow subtidal areas and minor channels where terrigenous sand and mud form the majority of the habitat *Natatolana tenuistylis*, *N. variguberna* and *N. taiti* are usually the numerically dominant scavengers, the species *N. angula* and *C. capricornica* may also be common. Among the subtidal rock and coral reef habitats *C. mekista*, *Cirolana* sp. 1 and *Cirolana* sp. 2 are usually the numerically dominant scavengers, *C. capricornica* may also be common. Intertidally, *C. capricornica* can be found on the rocky shores, *Pseudolana menartae* and *Excirolana orientalis* occur among the beach sediments. *Limicolana dinjerra* and *Cirolana* sp. 7 are scavengers in the creeks among mangroves.

Other scavengers collected in Darwin Harbour included nassariid gastropods, myodocopid ostracodes, lysianassoid amphipods, leptostracans and occasional decapods. None of these organisms were represented in the trap collections in numbers approaching those of the cirolanid isopods. The biomass of the isopods in some samples was very high (up to 287 g wet weight) and baits were often stripped to the bone in traps set for approximately 24 hours. This indicates that cirolanid isopods play an important role in the scavenging guild of Darwin Harbour as has been shown at localities such as Lizard Island, Queensland (Keable 1995).

ACKNOWLEDGMENTS

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APPENDIX 1 LIST OF COLLECTION STATIONS

All samples were collected by the author.

NT-119 middle of Woods Inlet, Darwin Harbour, Northern Territory, 12°28.4'S 129°46'E, baited trap, 8 m, unknown substrate - probably sediment, 7-8 July 1993.

NT-123 just off West Point on transect toward East Point, Darwin Harbour, Northern Territory, 12°26.3'S 129°46.3'E, baited trap, 8 m, unknown substrate - probably rocky reef, 8-9 July 1993.

NT-130 off Vesteys Beach, Fannie Bay, Darwin Harbour, Northern Territory, 12°25.8'S 129°49.1'E, baited trap, 10 m, unknown substrate - probably sediment, 9-10 July 1993.

NT-132 off northern end of sand spit, Fannie Bay, Darwin Harbour, Northern Territory, 12°26.0'S 129°48.4'E, baited trap, 9 m, sand, 9-10 July 1993.

NT-139 in channel to the west of the middle of Weed Reef, Darwin Harbour, Northern Territory, 12°30'S 129°47.6'E, baited trap, unknown substrate - probably sediment, 21 m, 11-12 July 1993.

NT-146 Middle Arm, west of Channel Island, Darwin Harbour, Northern Territory, 12°33.6'S 130°51.4'E, baited trap, unknown substrate - probably muddy sediment, channel edge, 20 m, 12-13 July 1993.

NT-148 Middle Arm, west of Channel Island, Darwin Harbour, Northern Territory, 12°33.7'S 130°50.7'E, baited trap, unknown substrate - probably muddy sediment, 2 m, 12-13 July 1993.

NT-149 south-west of Mandorah, Darwin Harbour, Northern Territory, 12°27.8'S 130°45.5'E, baited trap, on mud among prop roots of mangrove in tidal creek, intertidal - 0 m, 13-14 July 1993.

NT-152 Picnic Cove, Darwin Harbour, Northern Territory, 12°26.8'S 130°45.9'E, baited trap, sand beach, intertidal - 0 m, 13-14 July 1993.

NT-156 main channel off Bleesers Creek, East Arm, Darwin Harbour, Northern Territory, 12°29.4'S 130°52.2'E, baited trap, unknown substrate - probably muddy sediment, 12 m, 14-15 July 1993.

NT-157 between North Shell and South Shell Islands, East Arm, Darwin Harbour, Northern Territory, 12°29.7'S 130°52.9'E, baited trap, unknown substrate - probably rocks and muddy sediment, 7 m, 14-15 July 1993.

NT-161 just west of Talc Point, Woods Inlet, Darwin Harbour, Northern Territory, 12°28.7'S 130°46.6'E, baited trap, among beach rock and sand, intertidal - 0 m, 15-16 July 1993.

NT-171 Middle Arm, west of Channel Island, Darwin Harbour, Northern Territory, 12°33.7'S 130°50.6'E, baited trap, unknown substrate - probably muddy sediment, 10 m, 17-18 July 1993.

NT-175 Middle Arm, east of Channel Island, Darwin Harbour, Northern Territory, 12°33'S 130°52.3'E, baited trap, unknown substrate - probably coral, rocks and mud, 5 m, 17-18 July 1993.

NT-180 transect off Nightcliff toward Casuarina Beach, Darwin, Northern Territory, 12°20.6'S 130°50.4'E, baited trap, unknown substrate - probably sediment, 2 m, 18-19 July 1993.

NT-181 south-west of Mandorah, Darwin Harbour, Northern Territory, 12°27.8'S 130°45.5'E, baited trap, on coarse shelly sand just above mud among prop roots of mangrove in tidal creek, intertidal - 0 m, 13-14 July 1993.

NT-188 southern reaches of Middle Arm, Darwin Harbour, Northern Territory, 12°35.1'S 130°50.5'E, baited trap, unknown substrate - probably muddy sediment, centre of channel, 20 m, 21-22 July 1993.

A NEW GENUS AND THREE NEW SPECIES OF APSEUDOMORPH TANAIDACEAN (CRUSTACEA) FROM THE DARWIN REGION.

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ABSTRACT

Three new species of apseudomorph tanaidaceans, *Apseudes larakia* sp. nov., *Gutuapseudes manda* gen. et sp. nov. and *Apseudomorpha wagait* sp. nov., were common in coral rubble and algal habitats in shallow water in the Darwin area. These species and a new genus are described here.

KEYWORDS: Tanaidacea, Apseudomorpha, *Apseudes larakia* sp. nov., *Gutuapseudes manda* gen. et sp. nov., *Apseudomorpha wagait* sp. nov., new species, new genus, Darwin, Australia.

INTRODUCTION

Tanaidacean crustaceans are a diverse and ubiquitous component of macrobenthic communities worldwide (Holdich and Jones 1983), with epifaunal sampling programs generally yielding high numbers of tanaidomorph tanaidaceans (e.g., Edgar 1983) and infaunal samples often being dominated by apseudomorph tanaidaceans (e.g., Boesch 1973). However, despite their ecological importance, the taxonomy of Australian tanaidaceans is very poorly known, and tanaidaceans around Australia have been less well studied than on other continents. Twelve species of apseudomorph tanaidacean have been recorded from Australia, a number that certainly represents only a small fraction of the total species present (Sieg 1993).

During the Sixth International Marine Biological Workshop, The Marine Flora and Fauna of Darwin Harbour, tanaidaceans were collected from a variety of localities in the Darwin region. Three new species of apseudomorph tanaidacean occurred at several of the localities investigated, and are described here. Other less common species were also collected but await a comprehensive revision of the Australian fauna.

MATERIALS AND METHODS

Coral rubble, algae, sessile invertebrates and sediment were collected by the author (abbreviated below as GE) from shallow depths and enclosed underwater in plastic bags. The associated fauna was later extracted in the laboratory by adding a dilute formalin solution and examining material retained after passing washings through a sieve. Additional specimens were obtained from Dr P.A. Hutchings (abbreviated below as PH) who broke coral rubble samples into small pieces that were left in a container of seawater overnight, causing cryptofaunal species to move out of coral cavities. Specimens have been lodged with the Northern Territory Museum of Arts and Sciences, Darwin (NTM) and Museum of Victoria, Melbourne (NMV), with other collections presently remaining with the author.

SYSTEMATICS

Family APSEUDIDAE Leach, 1814
Genus *Apseudes* Leach, 1814
Apseudes larakia sp. nov.

Material examined. HOLOTYPE - NTM Cr.010944: 1 ovigerous female, 2.8 mm, East Point, Darwin Harbour, 7 m depth, 17 July 1993, coll. PH and GE, algal and coral rubble washings.

PARATYPES - NTM Cr.010945: 3 males (1 dissected onto 2 microscope slides), 1 ovigerous

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In: Hanley, J.R., Caswell, G., Megirian, D. and Larson, H.K. (eds) *Proceedings of the Sixth International Marine Biological Workshop. The marine flora and fauna of Darwin Harbour, Northern Territory, Australia.* Museums and Art Galleries of the Northern Territory and the Australian Marine Sciences Association: Darwin, Australia, 1997: 279–299.

female (dissected onto 2 microscope slides), 5 non-ovigerous females (1 dissected onto microscope slide), 2 damaged, locality data as for holotype. NTM Cr.010945: 4 males, 5 ovigerous females, 1 non-ovigerous female, South Shell Island, 2-8 m depth, 15 July 1993, coll. PH and GE. NMV J36015: 2 males, 1 ovigerous female, 4 non-ovigerous females, locality data as for holotype.

Other material - 3 males, 1 ovigerous female, 9 non-ovigerous females, 2 damaged specimens, Weed Reef, 3-8 m depth, 6-15 July 1993, coll. GE; 4 males, 13 ovigerous females, 35 non-ovigerous females, 12 juveniles and damaged specimens, Old Man Rock, Nightcliff, 1-6 m depth, 10-16 July 1993, coll. PH and GE; 3 males, 5 ovigerous females, 11 non-ovigerous females, 19 juveniles and damaged specimens, 2 km east of Charles Point, 1 m depth, 12 July 1993, coll. GE; 19 males, 10 ovigerous females, 20 non-ovigerous females, 4 juveniles and damaged specimens, South Shell Island, 2-8 m depth, 15 July 1993, coll. PH and GE; 2 males, 5 ovigerous females, 7 non-ovigerous females, 7 juveniles and damaged specimens, East Point, 8 m depth, 16 July 1993, coll. GE; 4 males, 3 ovigerous females, 7 non-ovigerous females, 6 juveniles and damaged specimens, Dudley Point, 7-8 m depth, 18 July 1993, coll. PH.

Description (based on female holotype and paratypes unless otherwise stated).

Body (Fig. 1). Elongated, depressed, length (rostrum to telson) 2.1-2.5 mm. Colour white.

Cephalothorax slightly longer than broad, one fifth as long as body, quadrangular behind eyes with slight narrowing anteriorly; rostrum gradually curved to tip; eye lobes present with visual elements.

Pereon occupies about 56% of total length; pereonite 1 width slightly more than twice length; pereonite 2 somewhat smaller than pereonite 1, slightly indented margin; pereonites 3-5 large with pereonite 4 largest, width 1.5 times length, indented margin; pereonite 6 width about twice length, slightly indented margin with several large plumose setae laterally.

Pleonites together one eighth as long as body; length of all five pleonites approximately equal but width diminishing posteriorly; lateral margins of pleonites pointed and backward directed; numerous long plumose setae on margins, with smaller plumose setae dorsolaterally.

Pleotelson (Fig. 2) slightly shorter than the five pleonites, length about 1.5 times width, produced posteriorly into blunt triangular tip; margin divided by two lateral bulges, each with two to four long plumose setae, long simple seta about halfway between posterolateral corner and midline.

Antenna 1 (Fig. 2). Peduncle with four articles; first article long, quadrangular, length about 4 times width, three simple setae and one pappose seta distally on outer margin and three simple setae two-thirds of the way along inner margin, with scattered simple and pappose setae; second article about half length of first, length 2.3 times width, about eight simple setae and two pappose setae distally; third article length about half that of second, length 1.5 times width, two long and one short seta distally; fourth article short, extension for inner flagellum approximately equal to base; outer flagellum seven-articulated with single long seta on second article, aesthetascs on fourth and sixth articles and long setae distally on last three articles; inner flagellum extending to end of fourth article of outer flagellum, two-articulated, articles narrow, first flagellar article with one distal seta, second article with three terminal setae and one pappose seta.

Antenna 2 (Fig. 2). Peduncle five-articulated, flagellum five-articulated; first article short, about as wide as long; second article twice as long as wide with short spiniform seta midway along inner margin and group of hairs midway along outer margin; scale linguiform with small seta midway along outer margin and three long terminal setae; third article annular with small seta distally on inner margin; fourth and fifth peduncular articles twice as long as third article and twice as long as broad, small pappose and simple setae distally; first three flagellar articles about equal in length with long distal setae on each; fourth flagellar article about 2/3 length of third flagellar article with long proximal and distal setae; fifth flagellar article about as long as fourth flagellar article, approximately five long terminal setae.

Mandibles (Fig. 1). Molar process well developed with broad grinding area; palp three-articulated, first article short with two or three long subterminal setae on inner margin, second article about 2.5 times as long as broad with six or seven long setae on distal half of inner margin, third article ovate, about two-thirds length of second article, distal half of inner margin with three or four setae of increasing size and three long setae terminally; spiniform setae row located on lobe, consisting of four strong

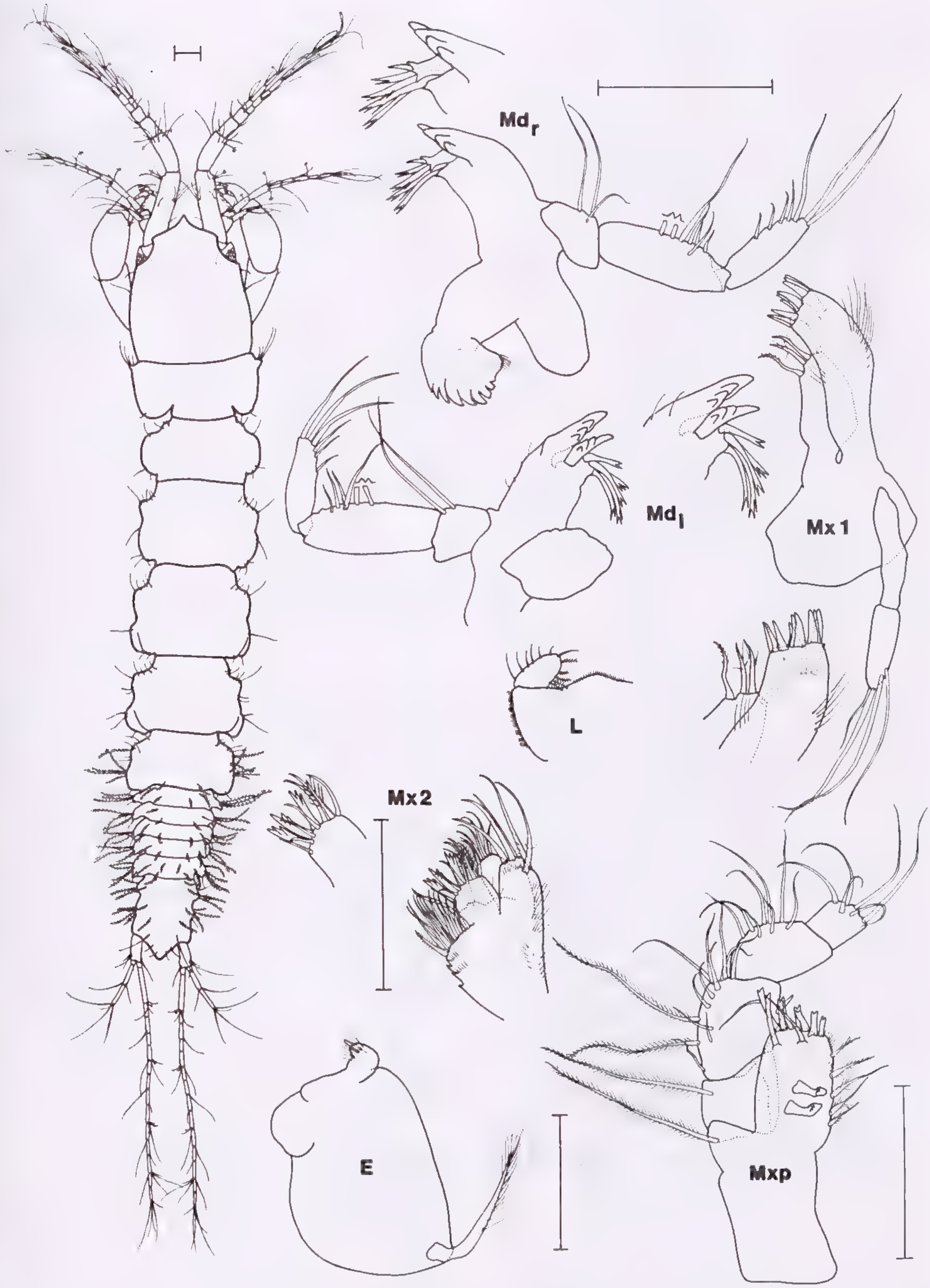

Fig. 1. *Apseudes larakia* sp. nov., female: dorsal view of whole animal, left mandible (Md_l), right mandible (Md_r), maxilla 1 (Mx1), maxilla 2 (Mx2), epignath (E), maxilliped (Mxp). (Whole animal drawn from holotype but with missing antennae and right cheliped added from paratype, mouthparts drawn from paratype.) Scale bar = 0.1 mm.

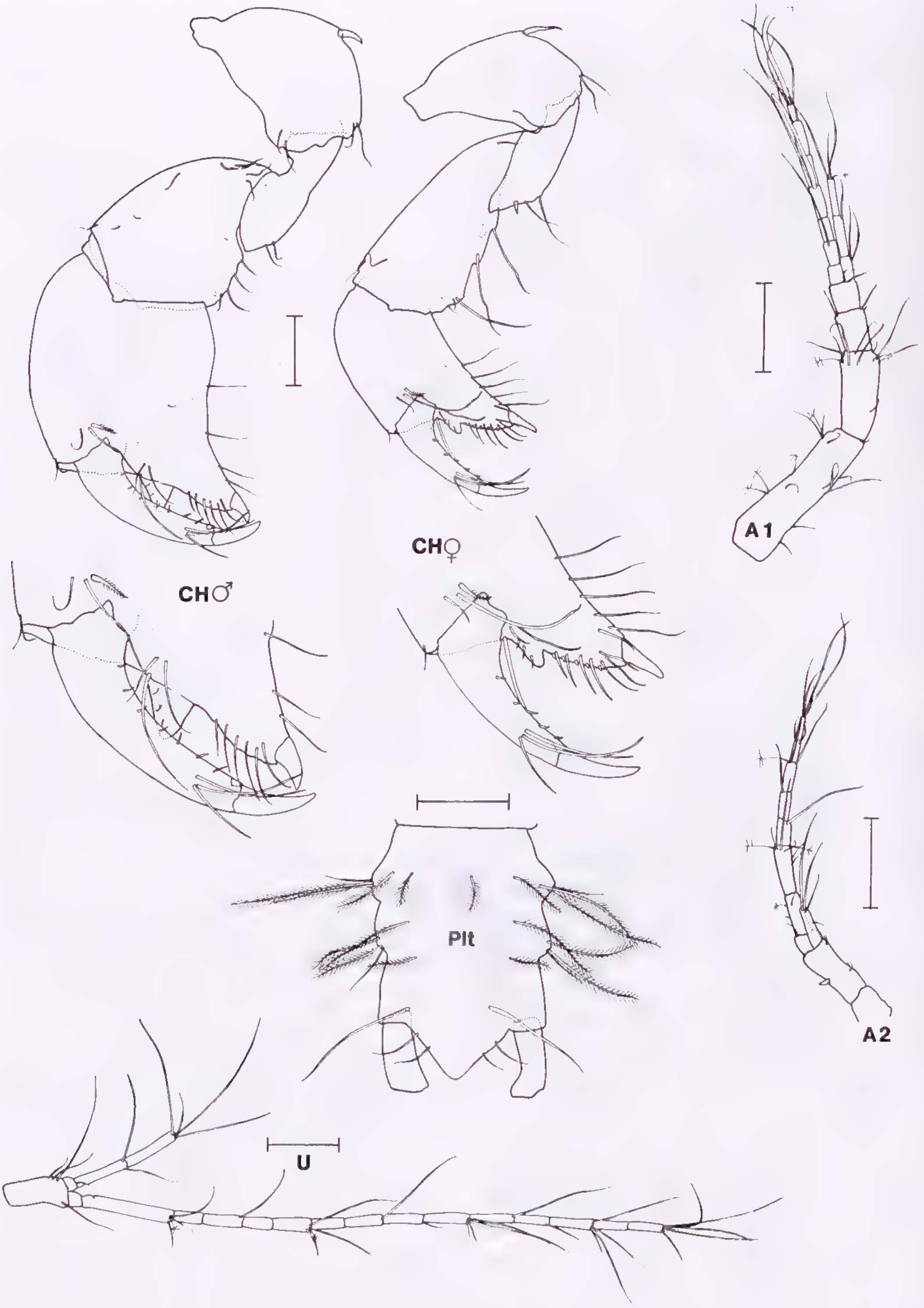

Fig. 2. *Apseudes larakia* sp. nov., female paratype: antenna 1 (A1), antenna 2 (A2), cheliped (CH), pleotelson (Plt), uropod (U). Cheliped (CH) of male paratype also included. Scale bar = 0.1 mm.

denticulate setae; lacinia mobilis well developed on left mandible with four rounded teeth, reduced to strong three-pointed process on right mandible; incisor process with four rounded teeth.

Maxilla 1 (Fig. 1). Outer endite with nine terminal spiniform setae, two subterminal spiniform setae, setules on outer margin; inner endite with rounded bulge midlength on inner margin, four denticulate setae terminally; palp elongate, length of articles about equal, with three or four long terminal setae.

Maxilla 2 (Fig. 1). First outer lobe with four or five long terminal setae; second lobe with about seven long setae; inner lobe proximally on inner edge with three projecting processes, followed by a single plumose seta and about 12 long simple setae, with large plumose seta behind; outer edge with three denticulate setae, row of about seven simple setae and one plumose seta, large plumose seta behind.

Labium (Fig. 1). Bilobed; inner and outer distal margin with setules, lobe with four plumose setae on inner margin, about six small simple setae around outer margin, one small simple seta terminally.

Maxilliped (Fig. 1). Medially unfused; proximal section of basis about twice as long as broad, with long plumose seta near articulation with palp; endite well developed, about eight barbed setae near terminal margin, long inner distal seta, medial margin with two coupling hooks and row of five pappose setae; palp four-articulated, first article annular and short with one very long plumose seta, second article distally expanded with two very long plumose and about 10 long simple setae near margin, third article similar to second but with about eight setae in two rows near margin, fourth article square, about half length of third article, terminating in six long setae.

Epignath (Fig. 1). Rounded; terminal projection plumose, length about equal to epignath width; small rounded accessory lobe with setules near outer edge.

Cheliped (female; Fig. 2). Large and solid, held parallel to body; basis ovate, about twice as long as broad, narrow proximally, large spiniform seta about halfway along rounded ventral margin, two simple setae in ventrodistal corner; exopodite absent; merus length about twice width, narrow proximally, produced into tooth distally, with spiniform seta and three simple setae on ventrodistal margin; carpus triangular, length twice width, inserted into two-thirds length of merus, with three large simple setae on ventral surface; propodus length 1.5 times width, quadrangular hand, plumose seta and two simple setae below articulation with dactylus, single long and short setae in corner, large tooth on dorsal margin of thumb, row of simple setae along upper and lower margins of thumb, large terminal spiniform seta; dactylus smooth, group of three large simple setae on side, about five small simple setae along lower margin, claw well developed.

Cheliped (male, 2.6 mm length; Fig. 2). Very solid, subchelate; basis wide, about 1.5 times as long as broad, narrow proximally, large spiniform seta midway along semicircular ventral margin; exopodite absent; merus length about three times width, narrowest about one third distance to distal end, rounded tooth on distal corner with two subterminal setae; carpus triangular, length 1.3 times width, with three prominent and two minor setae on ventral surface; propodus hand square, plumose seta and two simple setae below articulation with dactylus, several long simple setae in corner of articulation, upper margin of thumb straight apart from very large tooth proximally, row of simple setae along distal half of upper margin of thumb, two setae subterminal on lower margin of thumb and two setae further along on ventral margin of hand, solid and wide terminal spiniform seta; dactylus smooth, group of three large setae at two thirds distance along side, about seven small setae distributed evenly along lower margin, claw well developed.

Pereopod 1 (Fig. 3). Laterally flattened, of digging type; coxa produced anteriorly into small spine with three to five simple setae; basis elongate, about 2.5 times as long as broad, three or four plumose setae on dorsal margin, one very large plumose seta on ventral margin, three simple setae distally on ventral margin; exopodite absent; ischium quadrate, about 1.5 times as wide as long, three to four simple setae distally on ventral margin; merus expanded distally, about 1.5 times as long as wide, a distal spiniform seta on ventral and dorsal margins, ventral margin with group of five long simple setae midway, dorsal margin with two long simple setae distally; carpus about two-thirds length of merus, spiniform setae midway and distally on ventral margin and distally on dorsal margin, four long simple setae along ventral margin, two setae midway along dorsal

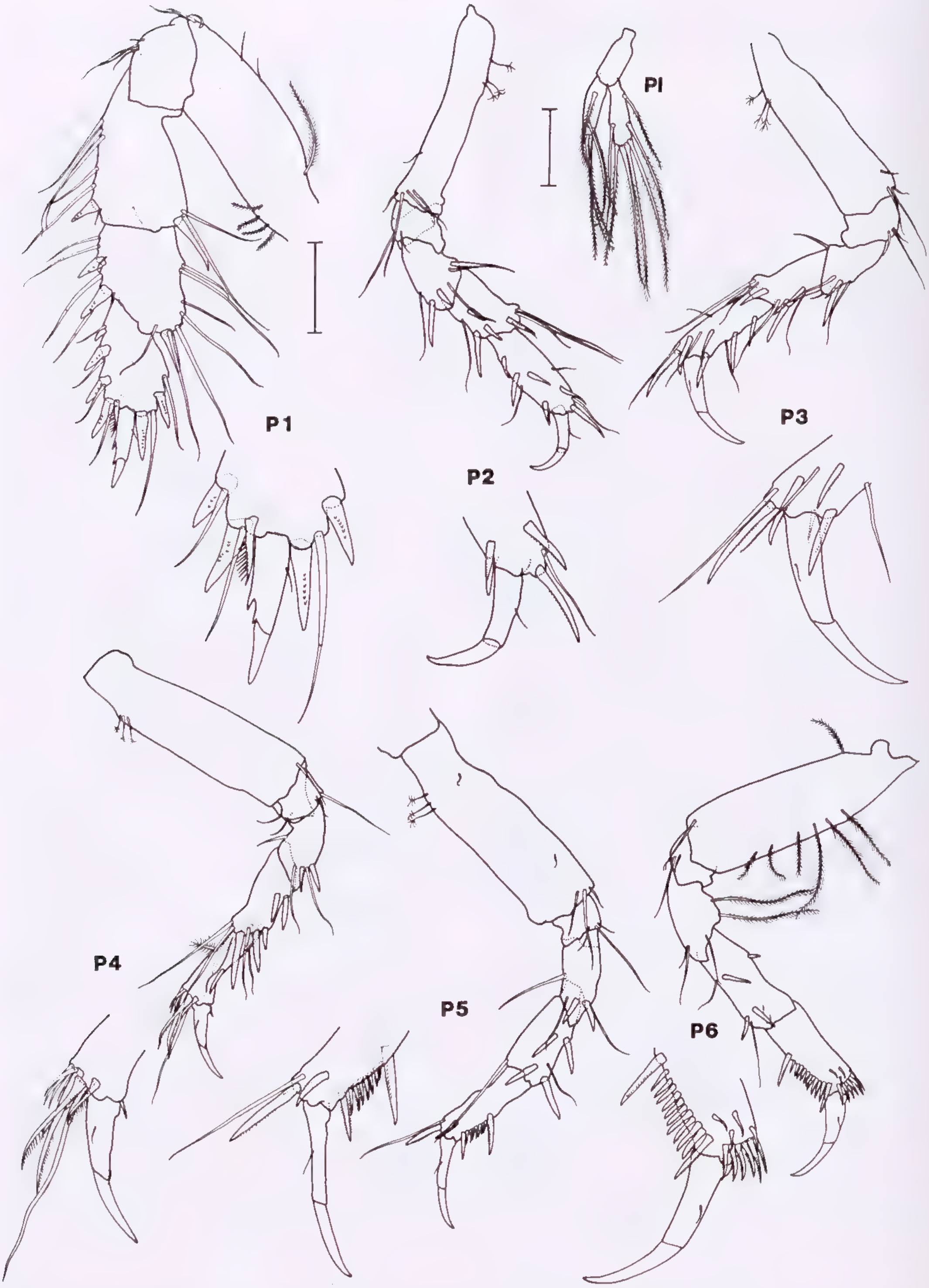

Fig. 3. *Apseudes larakia* sp. nov., female paratype: pereopods 1 to 6 (P1-6), pleopod (Pl). Scale bar = 0.1 mm.

margin, five setae distally on dorsal margin; propodus about two-thirds width of carpus and same length, three solid spiniform setae evenly spaced on ventral margin from halfway to articulation with dactylus, subterminal spiniform seta and spiniform seta halfway on dorsal margin, one small pectinate spiniform seta near articulation with dactylus, long simple setae between spiniform setae; dactylus with claw, ventral edge with one sharp serration.

Pereopod 2 (Fig. 3). Slender, of walking type; basis elongate, about six times as long as broad, three pappose setae proximally on dorsal margin, three to five simple setae distally on ventral margin; ischium annular, three to four simple setae distally on ventral margin; merus elongate distally, about two-thirds as long as wide, two to three spiniform setae and two to three simple setae distally; carpus slightly longer than merus, widened distally, 1.5 times as long as wide, one long and two short spiniform setae distally, one short spiniform seta midway along side, three to four simple setae distally, one seta midway along ventral margin; propodus elongate, 1.5 times as long as carpus, slightly more than twice as long as wide, one small spiniform seta one quarter way and two spiniform setae halfway between merus and dactylus, two small spiniform setae on ventral side and two large spiniform setae and one long simple seta on dorsal side of articulation with dactylus; dactylus long and recurved, base about equal in length to large claw, hair halfway along dorsal margin.

Pereopod 3 (Fig. 3). Similar in shape and general proportions to pereopod 2 except that basis and ischium are slightly wider and other segments slightly narrower; basis, ischium and merus similar in armament to on pereopod 2; carpus with one long and two short spiniform setae distally and one spiniform seta midway, three to four simple setae distally and single seta midway along ventral margin; propodus with two spiniform setae on ventral margin, four spiniform setae subterminal around articulation with dactylus, single setae midway along dorsal and ventral margins and several subterminal setae; dactylus very long and recurved, subequal in length to propodus, hair halfway along dorsal margin, long recurved claw.

Pereopod 4 (Fig. 3). Similar in shape and proportions to pereopod 3; basis, ischium, merus and dactylus similar in armament to on pereopod 3; carpus with two proximal and five distal spiniform setae, several distal setae; propodus with strong feathered hair proximally on dorsal margin, six to eight pectinate setae and one very large simple seta distally, one short spiniform seta two-thirds way along ventral margin.

Pereopod 5 (Fig. 3). Similar in shape and proportions to pereopod 3; basis, ischium, merus and dactylus similar in armament to on pereopod 3; carpus with two proximal spiniform setae, two distal spiniform setae and two long distal setae; propodus with comb of two long serrated setae either side of row of six or seven short pectinate setae along distal half of ventral margin, one large serrated distal seta, one smaller distal spiniform seta, one long and one short distal simple setae.

Pereopod 6 (Fig. 3). Basis elongate, about three times as long as wide, one long plumose seta proximally on ventral margin, six long plumose setae spaced equidistantly near dorsal margin, one distal spiniform seta; ischium annular, one long and several short simple setae distally on ventral margin; merus about one and a half times as long as wide, dorsal margin rounded and with two very long plumose setae, several distal simple setae; carpus three times as long as wide, two spiniform setae midway, two spiniform setae and several simple setae subterminally; propodus slightly shorter than carpus, distal row of five short pectinate setae, ventral row of nine or ten short pectinate setae distally with long spiniform setae on either end, several short subterminal spiniform setae; dactylus similar to on pereopod 3.

Pleopods (Fig. 3). Five pairs, biramous, all similar; peduncle ovate, about twice as long as wide, lacking setae; rami with single article, subequal, about three times as long as wide, encircled by seven or eight long plumose setae.

Uropods (Fig. 2). Biramous, filiform; peduncle small, about twice as long as wide, distal half with about five setae; endopodite long, with about 15 articles; first article small, rounded, length approximately equal to width; second article long, about 6.5 times as long as wide, with three simple setae and single pappose seta distally; remaining articles three to four times as wide as long, setae often present distally; exopodite three-articulated, first article short, about 1.5 times as wide as long, second article about six times as long as broad with two long distal setae, third article similar to second article, with four long terminal setae.

Etymology. The species name refers to a local aboriginal linguistic group.

Distribution. Darwin region, Australia; 1-8 m depth.

Remarks. *Apseudes larakia* differs from the other three Australian species of *Apseudes (Apseudes australis* Haswell, 1882, *Apseudes caeruleus* Boesch, 1973, *Apseudes estuarius* Boesch, 1973) in a number of features, including having uropods with three-articulated exopodites. The subchelate cheliped of *A. larakia* is unusual amongst tropical species belonging to the genus *Apseudes*, although they somewhat resemble the cheliped of the Japanese species *Apseudes littoralis* Shiino, 1952; however, that species differs by possessing exopodites on cheliped and pereopod 1, and having rounded lateral margins on pleonites. *Apseudes larakia* differs from other *Apseudes* species by the combination of subchelate cheliped lacking exopodite, antenna 2 with linguiform scale, endite of maxilliped with two locking hooks, and exopodite of uropod with three articles. The magnitude of differences between *Apseudes larakia* and other species in the genus, particularly the lack of exopodite on cheliped and pereopod 1 and linguiform scale on antenna 2, indicates that a new genus to include *Apseudes larakia* may be warranted if closely related species are discovered in the future.

Apseudes larakia is by far the most abundant and widely-distributed species found in shallow water in the Darwin region. The species is probably epifaunal as large numbers of animals were collected from algae such as *Halimeda* spp.

Family APSEUDIDAE Leach, 1814

Gutuapseudes gen. nov.

Diagnosis. Body dorsoventrally flattened; carapace with ocular lobes; pereonites 4-6 lobed posteriorly; pleonites with very long lateral plumose setae; antenna 1 with inner and outer multi-articulated flagella of about equal length; antenna 2 with well developed scale; mandibles with three-articulated palp; maxilla 1 with two-articulated palp; cheliped slender with three-articulated exopodite; pereopod 1 without exopodite, coxa lacking spiniform apophysis, carpus rounded with numerous long setae; pereopods 2-5 with numerous long spines and setae on carpus and propodus; pereopod 6 with long plumose setae near margins of merus and carpus; pleopod with long plumose setae; uropod with very long endopodite, exopodite with numerous articles.

Type-species. *Gutuapseudes manda* sp. nov.

Etymology. The name honours the numerous studies on apseudomorph tanaidaceans carried out by Prof. Modest Gutu.

Gender. Masculine.

Remarks. Because of a lack of spiniform processes projecting from the sides of pereonite 1 and the lack of a transverse row of hairs on the first pereonite, *Gutuapseudes* falls within family Parapseudidae Gutu, 1981. However, until a degree of consensus is reached regarding the status of the family Parapseudidae (compare, for example, Gutu 1981, and Sieg 1984), *Gutuapseudes* has conservatively been classed within the Apseudidae; it lies within section III of the superfamily Apseudoidea as defined by Sieg (1984).

Gutuapseudes is closely-related to another recently described genus from the Darwin region, *Bilobatus* Sieg, 1993. Characters shared by the two genera include lack of anteriorly-directed spine-like process at the sides of pereopod 1, elongate chelipeds with large exopodite, pereopod 1 lacking exopodite, pleopods with exopodite similar to endopodite, and elongate pleotelson. *Gutuapseudes* differs from *Bilobatus* by having a maxilla 1 with two-articulated palp, fewer spiniform setae on pereopod 1, and antenna 1 with inner flagellum of similar size to outer flagellum. It also lacks the distinctively cleft lateral margins on pereonites 4-6 that characterise *Bilobatus*. The great width of the carpus and numerous long setae on pereopod 1 of *Gutuapseudes* indicate affinities with *Halmyrapseudes* Bacescu and Gutu, 1974 and *Discapseudes* Bacescu and Gutu, 1975, although *Gutuapseudes* differs from these genera in several characters, including the presence of flagellae of equal length on antennae 1 and the lack of exopodite on pereopod 1.

Gutuapseudes manda sp. nov.

Material examined. HOLOTYPE - NTM Cr.010947: 1 female, 4.3 mm, Weed Reef, Darwin Harbour, 4-8 m depth, algal and coral rubble washings, 15 July 1993, coll. GE.

PARATYPES - NTM Cr.010948: 1 female (dissected on 3 microscope slides), Old Man

Point, Nightcliff, 1 m depth, 10 July 1993, coll. GE; NTM Cr.010949: 1 damaged ovigerous female, South Shell Island, 2 m depth, 12 July 1993, coll. PH; NMV J36014: 1 ovigerous female, 1 damaged specimen, South Shell Island, 2 m depth, 15 July 1993, coll. PH and GE.

Other material - 1 non-ovigerous female, 4 juveniles and damaged specimens, locality data as for holotype; 1 non-ovigerous female, 1 damaged specimen, Lee Point, 2 m depth, 11 July 1993, coll. PH; 1 non-ovigerous female, 1 damaged specimen, South Shell Island, 2 m depth, 15 July 1993, coll. PH and GE.

Description (based on female holotype and paratypes unless otherwise stated).

Body (Fig. 4). Elongated, depressed, length (rostrum to telson) 4.5-5.3 mm. Colour white. Thin cuticle.

Cephalothorax length equal to width, one sixth as long as body, quadrangular with slight anterior narrowing; rostrum gradually curved to blunt tip; eye lobes present; epistome and sternite of thoracomere 2 each with medial spine.

Pereon about half as long as body. Pereonite 1 width about twice length; ventral spine present medially. Pereonite 2 slightly smaller than pereonite 1; ventral spine present medially. Pereonites 3-6 longer and slightly narrower than pereonite 2, large rounded lobe towards rear of lateral margin.

Pleonites together one sixth as long as body; length of all five pleonites approximately equal but width diminishing posteriorly; epimera pointed and backward directed, most prominent on pleonite 5; several long plumose setae on margins.

Pleotelson (Fig. 5) two thirds length of the five pleonites, length slightly longer than width; posterior margin with small rounded knob and two long plumose setae centrally, several small plumose and simple setae diminishing in size away from centre; lateral margins slightly rounded, each with several long simple and pappose setae.

Antenna 1 (Fig. 5). Peduncle with four articles; first article long, quadrangular, length about 3 times width; numerous simple and pappose setae on margins; second article about half length of first, length about twice width, four simple setae midway and about eight simple setae distally; third article length about half that of second, length 1.5 times width, eight to ten simple setae at distal end; fourth article short, extension for inner flagellum approximately equal to base; outer flagellum long, 15-articulated with articles narrow, first flagellar article length 1.5 times width, with small seta, second article length equal to width, remaining articles length 2-4 times width, distal setae on alternating articles, aesthetascs on seventh, ninth, eleventh and thirteenth articles; inner flagellum approximately equal in lenth to outer flagellum, with 15-16 elongate articles, length 2-4 times width, long setae distally.

Antenna 2 (Fig. 5). Peduncle five-articulated, flagellum 10-articulated; first article short, about as wide as long; second article 1.7 times as long as wide with distal seta on inner margin; scale elongate, three times as long as wide, with eight setae around margin; third article annular, produced distally into spine on inner margin; fourth article about as long as wide with small simple and pappose setae distally on inner margin; fifth peduncular article 1.5 times as long as wide, small pappose seta distally and several simple setae on outer margin; flagellar articles arranged in five pairs, articles approximately equal in length but diminishing distally in length, first flagellar article of each pair usually with short setae only, second flagellar article of each pair with several long and short distal setae, aesthetascs present distally on fourth and sixth flagellar articles.

Mandibles (Fig. 4). Molar process well developed with broad grinding area; palp three-articulated, first article expanded distally, length 1.5 times width, with numerous long simple setae, second article quadrangular, about 3.5 times as long as broad, with eight pectinate setae on distal half of inner margin and one seta slightly inside, third article triangular, with row of nine finely-pectinate setae along distal half of inner margin and two very long simple setae terminally; row of spiniform setae located on lobe, consisting of four or five denticulate setae; lacinia mobilis well developed on left mandible with four rounded teeth, reduced to a strong three-pointed process on right mandible; incisor process with five rounded teeth.

Maxilla 1 (Fig. 4). Outer endite with eleven terminal spiniform setae, outer row with three, middle and inner rows each with four setae, two barbed setae subterminally, setules on outer margin, smallest setules distally; inner endite leaflike, two plumose and two simple spine-like setae terminally, setules along outer margin; palp elongate, second article slightly shorter

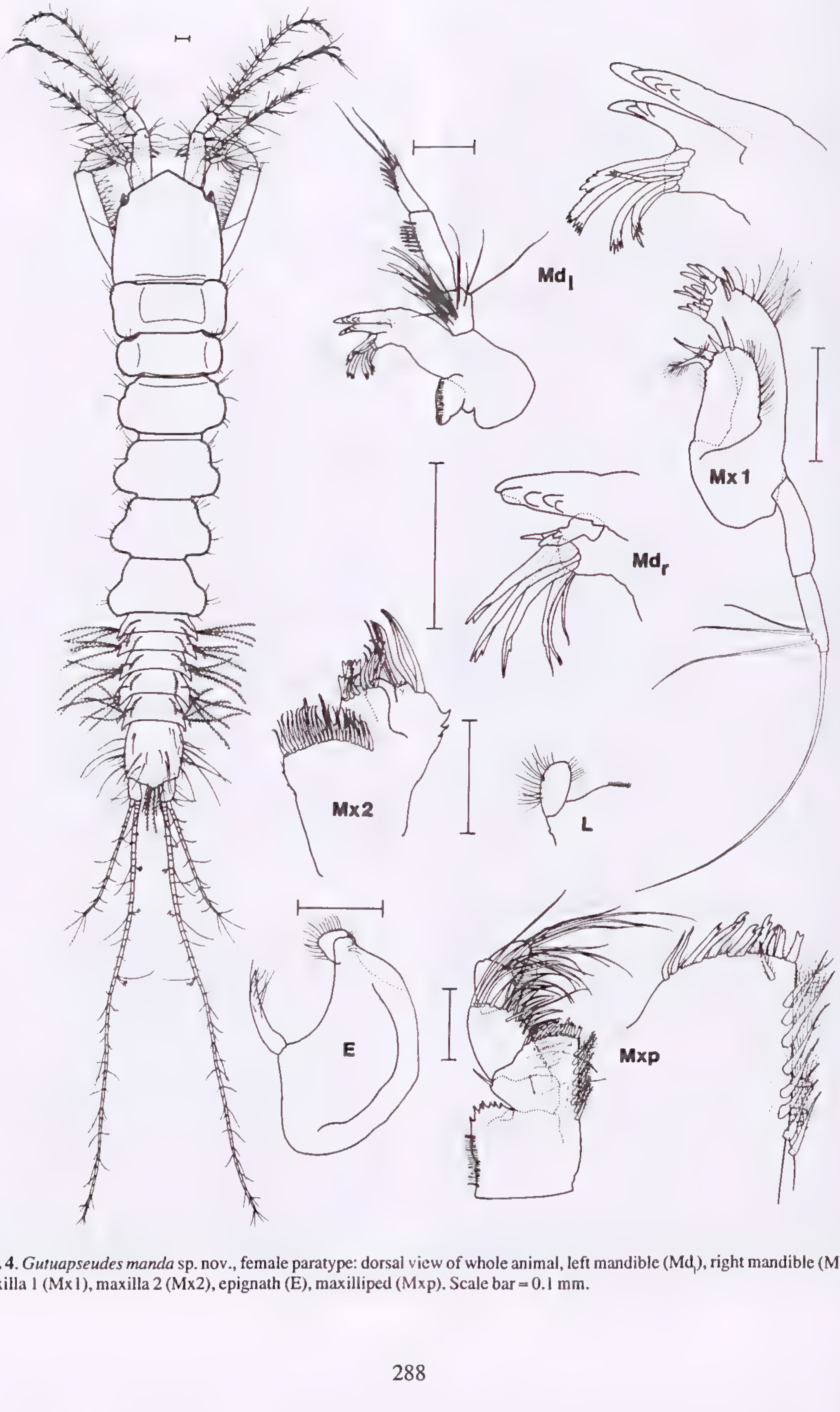

Fig. 4. *Gutuapseudes manda* sp. nov., female paratype: dorsal view of whole animal, left mandible (Md_l), right mandible (Md_r), maxilla 1 (Mx1), maxilla 2 (Mx2), epignath (E), maxilliped (Mxp). Scale bar = 0.1 mm.

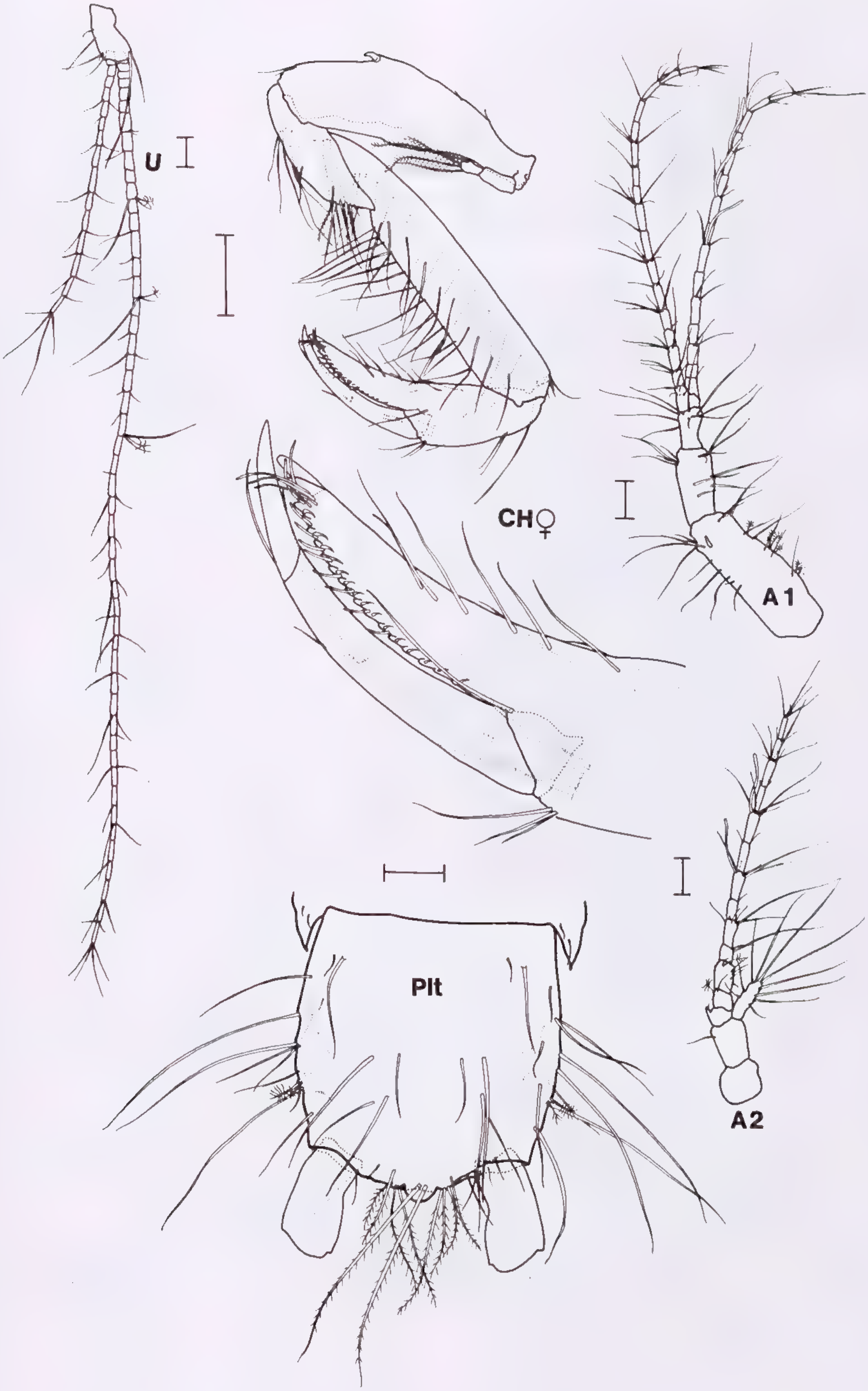

Fig. 5. *Gutuapseudes manda* sp. nov., female paratype: antenna 1 (A1), antenna 2 (A2), chelipeds (CH), pleotelson (Plt), uropods (U). Scale bar = 0.1 mm.

than first, with one very long and three long terminal setae.

Maxilla 2 (Fig. 4). First outer lobe proximally with three sharp projections in margin, distally with four long pectinate and two simple terminal setae; second lobe with about four setae; inner lobe proximally on inner edge with four small hairs, followed by row of about 24 long setae with two setae behind; outer edge with several denticulate setae and about four simple setae.

Labium (Fig. 4). Bilobed, outer margin with spine-like projection distally, inner margin with setules, lobe with about eight small setae on inner margin and numerous setae on outer margin.

Maxilliped (Fig. 4). Medially unfused; basis proximally wider than long, with short seta followed by about 25 setules proximally on outer margin, five to seven spine-like projections in distal outer margin; endite well developed, about 12 barbed setae near terminal margin, barbed inner distal seta, medial margin with three coupling hooks and row of eight pappose setae; palp four-articulated, first article short and distally expanded, about twice as wide as long, with three simple setae, second article quadrangular, 1.4 times as long as wide, with numerous pairs of simple setae along inner and distal margins, third article distally expanded, slightly longer than wide, with six or seven pairs of simple setae along distal inner margin, fourth article two-thirds length of third article, terminating in seven to nine long setae.

Epignath (Fig. 4). Broad, cup-shaped; terminal projection with about seven small setae, length about two-thirds epignath width; small rounded accessory lobe with setules near outer edge.

Cheliped (female) (Fig. 5). Slender with exopodite; basis expanded distally, about 3.5 times as long as broad, spiniform seta two-thirds way along convex ventral margin, two small setae in ventrodistal corner; exopodite three-articulated, first and third articles half length of second, four long setae terminally; merus triangular, half length of basis, produced into tooth distally, with three groups of five or six simple setae and single long plumose seta; carpus elongate, slightly expanded distally, length four times width, with 7-12 large simple setae arranged evenly in each of three lines along ventral half and one long and several short setae dorsodistally; propodus hand triangular, length 1.5 times width, two setae about one-third way and several setae adjacent to articulation with dactylus; propodus thumb slender, with row of serrations and small setae along dorsal margin, row of four large setae along lower margin with several other setae nearby, solid terminal spiniform seta; dactylus smooth, a group of two large setae one-third way and another group of three setae two-thirds way along side, claw long and well developed.

Cheliped (male). Not observed.

Pereopod 1 (Fig. 6). Laterally flattened, of digging type; basis elongate, about 3.3 times as long as broad, several setae distally on ventral margin, exopodite absent; ischium annular, three times as wide as long, three large and two small setae distally on ventral margin; merus expanded distally, about twice as long as wide, one long spiniform seta and group of about eight long simple setae distally on dorsal margin, one short blunt spiniform seta and group of about eight long simple setae distally on ventral margin, five long setae along distal third of ventral margin, row of ten setae and several other adjacent setae midway near ventral margin; carpus rounded, slightly shorter than merus, row of eight long simple setae along ventral margin with large spiniform seta at distal end, row of 8-10 long setae near dorsal margin followed by distal spiniform seta and about eight thin simple setae along distal margin; propodus rounded, similar in length to carpus but about three-quarters width, single spiniform setae either side of articulation with dactylus and spiniform seta halfway along ventral margin, about 20 simple setae equidistant around margin and small pectinate setae next to articulation with dactylus; dactylus with claw, ventral margin with two to four small spiniform setae, hair at base of claw.

Pereopod 2 (Fig. 6). Slender, of walking type; basis elongate, about four times as long as wide, three pappose setae proximally on dorsal margin, pappose seta proximally and several long simple setae distally on ventral margin; ischium slightly wider than long, with one or two simple setae on dorsal margin and group of about six setae distally on ventral margin; merus expanded distally, with narrow spiniform seta distally on ventral margin, six to eight setae near ventral margin, one spiniform seta distally on dorsal margin; carpus nearly twice as long as merus, width decreasing distally, single spiniform seta distally on ventral margin, group

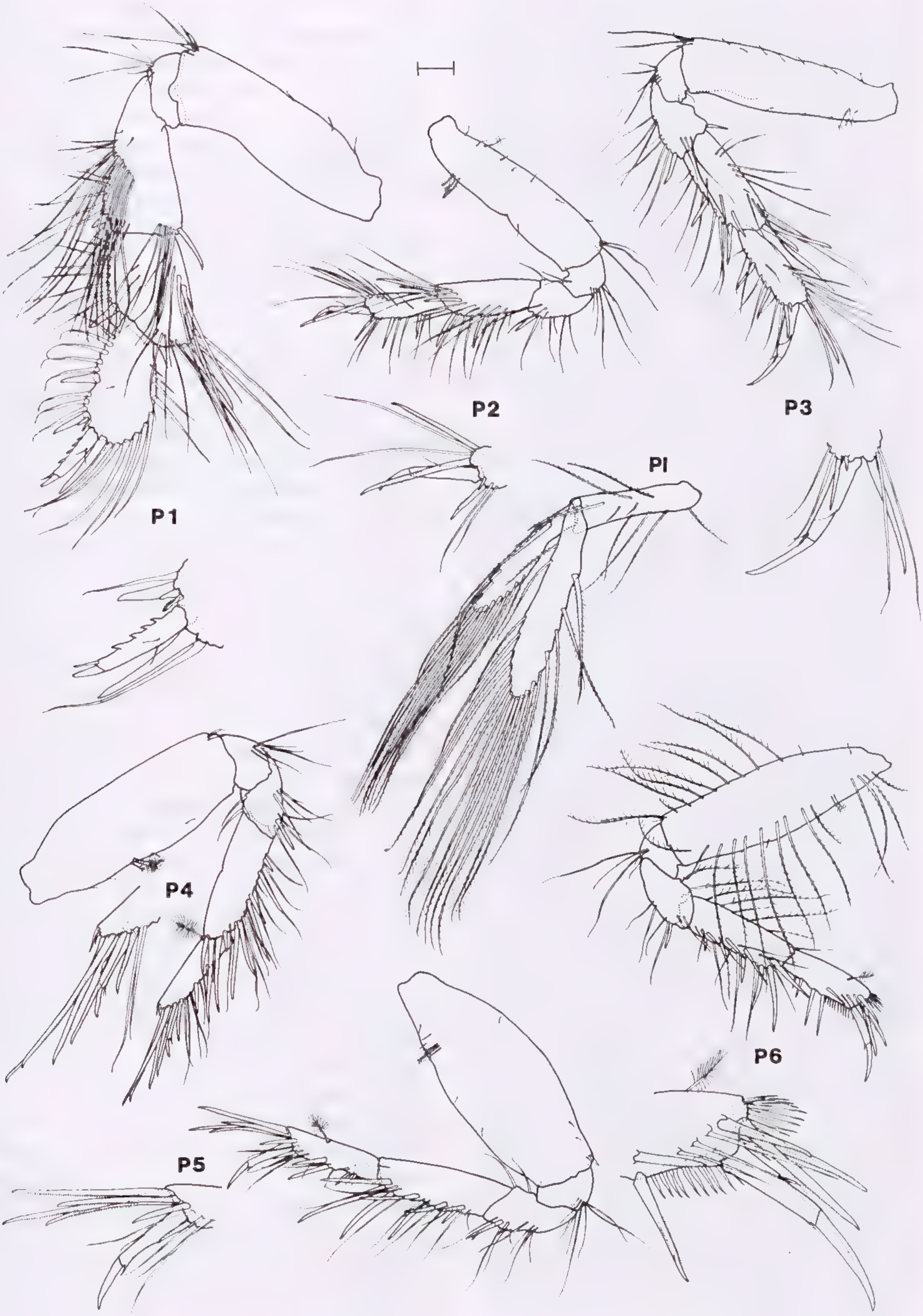

Fig. 6. *Gutuapseudes manda* sp. nov., female paratype: pereopods 1 to 6 (P1-6), pleopod (Pl). Scale bar = 0.1 mm.

of five or six narrow barbed setae of various sizes terminally, numerous setae near ventral and distal margins; propodus elongate, three-quarters length and width of carpus, with two narrow spiniform setae and six long simple setae along ventral margin, one narrow and one very short spiniform seta on ventral side and two long narrow barbed setae on dorsal side of articulation with dactylus, row of about seven long setae running diagonally near dorsal margin distally; dactylus long and recurved, slightly shorter than propodus, with one hair halfway and one at base of large claw.

Pereopod 3 (Fig. 6). Similar in shape and general proportions to pereopod 2; basis, ischium and merus similar in armament to on pereopod 2; carpus with one spiniform seta distally and one spiniform seta midway along ventral margin, two spiniform setae distally along dorsal margin, one spiniform seta distally on side, numerous long setae along dorsal and ventral margins; propodus similar to on pereopod 2 except that only one long narrow spiniform seta is present on dorsal side of articulation with dactylus; dactylus very long and recurved, slightly longer than propodus.

Pereopod 4 (Fig. 6). Similar in shape and proportions to pereopod 3 except that basis and ischium are wider and propodus narrower; basis, ischium and merus similar in armament to on pereopod 3; carpus with small proximal spiniform seta followed by seven to nine longer spiniform setae near ventral and distal margins, numerous ventral setae; propodus with feathered seta at articulation with carpus on dorsal margin, two narrow barbed setae and about seven long simple setae along ventral margin, five long narrow barbed setae around articulation with dactylus; dactylus with thin spine-like projection at base of claw.

Pereopod 5 (Fig. 6). Similar in shape and proportions to pereopod 4 except for wider basis with length 2.5 times width; basis, ischium, merus, carpus and dactylus similar in armament to on pereopod 4; propodus with strong feathered hair three-fifths distance along dorsal margin, pair of short spiniform setae one-third way and pair of long spiniform setae two-thirds way along ventral margin with adjacent simple setae, six barbed setae around articulation with dactylus.

Pereopod 6 (Fig. 6). Basis approximately ovate, about three times as long as wide, with about nine long and three smaller plumose setae near ventral margin, about thirteen long and three smaller plumose setae near dorsal margin; ischium annular, several simple setae distally on ventral margin; merus about 1.5 times as long as wide, dorsal margin with two long plumose setae, four simple setae and narrow spiniform seta distally near ventral edge; carpus quadrangular, three times as long as wide, with four pairs of spiniform setae increasing in length distally down ventral margin, additional unpaired spiniform seta proximal to largest spiniform setae pair, numerous simple setae near ventral margin and five large plumose seta followed by simple seta equidistant along dorsal margin; propodus slightly shorter than carpus, with ventrodistal comb of about 27 small pectinate setae, three spiniform setae along ventral margin, three terminal barbed setae and several terminal simple setae; dactylus with thin spine-like projection at base of long claw, hair midway.

Pleopods (Fig. 6). Five pairs, biramous, all similar; peduncle narrow, about 4.5 times as long as wide, with three or four flexible plumose setae on both inner and outer sides; rami with single article, narrow, elongate, length about six times width, densely surrounded by stiff plumose setae, exopodite about 1.5 times length of endopodite.

Uropods (Fig. 5). Biramous, filiform; peduncle small, about three times as long as wide, four simple setae distally and two on outer margin; endopodite very long, slightly more than half body length, with about 48 articles; first four articles small, length less than or equal to width, other articles long, generally two to three times as long as wide, with long simple setae distally on about every second article; exopodite long, about 16-articulated and one-third length of exopodite, most articles with distal setae and generally two to four times as long as wide.

Etymology. The species name refers to a local aboriginal linguistic group.

Distribution. Darwin region, Australia; 2-8 m depth.

Remarks. *Gutuapseudes manda* is the only known apseudomorph tanaidacean with the characters of the genus. It can be readily distinguished from other apseudomorph tanaidaceans in Australia, and virtually all worldwide, by carrying only two spiniform setae amongst numerous long simple setae on the ventral margin of the propodus of pereopod 1. One of these spiniform setae is located in a slight concavity midway along the margin.

Gutuapseudes manda was collected primarily from amongst coral rubble and is probably cryptofaunal.

Family METAPSEUDES Lang, 1970

Genus *Apseudomorpha* Miller, 1940

Apseudomorpha wagait sp. nov.

Material examined. HOLOTYPE - NTM Cr.010950: 1 ovigerous female, East Point, 8 m depth, coral and algal rubble, 16 July 1993, coll. GE, 1.8 mm.

PARATYPES - NTM Cr.010951: 1 male (dissected onto 2 microscope slides), 1 ovigerous female (dissected onto 2 microscope slides), locality data as for holotype; 3 males, 1 ovigerous female, 2 non-ovigerous females, Lee Point, 2 m depth, 16 July 1993, coll. PH. NMV J36013: 3 males, 1 ovigerous female, 2 non-ovigerous females, Lee Point, 2 m depth, 16 July 1993, coll. PH.

Other material - 1 ovigerous female, 4 non-ovigerous females, 5 juveniles and damaged specimens, Lee Point, 2 m depth, 16 July 1993, Coll. PH; 6 non-ovigerous females, East Point, 8 m depth, 16 July 1993, coll. GE; 4 males, 2 non-ovigerous females, 5 juveniles and damaged specimens, West Point, 6-7 m depth, 18 July 1993, coll. PH.

Description (based on female holotype and paratypes unless otherwise stated).

Body (Fig. 7). Elongated, depressed, length (rostrum to telson) 1.4-1.6 mm. Colour white, no obvious markings; thick cuticle.

Cephalothorax slightly shorter than broad, one quarter as long as body, widest posteriorly, margins indented between two flat lobes, paired setae present in marginal indentation, additional setae in indistinct grooves dorsolaterally; rostrum produced to sharp tip; eye lobes present.

Pereon occupies about 63% of total length; pereonite 1 width more than twice length, lateral edge rounded, with two setae anteriorly on each margin, two setae each side of dorsal midline; pereonites 2 and 3 slightly longer than pereonite 1, length about equal to twice width, lateral margin forming a large rounded lobe posteriorly, with two setae anteriorly on each lateral margin, three setae each side of dorsal midline; pereonites 4 and 5 slightly smaller than pereonite 2 but with similar proportions and setation, lateral margin indented and divided into two lobes with anterior lobe smallest; pereonite 6 width 2.4 times length, lateral margin indented and divided into two lobes, setation similar to pereonite 5.

Pleonite segments compressed, total length equal to pereonite 6; length of all five pleonites approximately equal, pleonite 3 width greatest, lateral margins extended posteriorly; single seta on lateral margins of pereonites 2 and 3, long simple seta each side of dorsal midline on pereonites 1 and 2.

Pleotelson (Fig. 8) slightly longer than the five pleonites, width 1.7 times width, produced posteriorly into blunt triangular tip, margin rounded; long seta posteriorly and medium-sized seta anteriorly on each side of dorsal midline, short setae either side of posterior tip.

Antenna 1 (Fig. 8). Peduncle four-articulated; first article long, quadrangular, length about four times width; three strong spiniform setae with associated plumose setae one-third to two-thirds distance along inner margin, spiniform seta and plumose seta distally on inner margin, plumose setae midway and at either end of outer margin, about 12 small simple and pappose setae scattered about; second article less than one third length of first, length 1.5 times width, plumose seta and several small hairs distally on inner margin, several simple and pappose setae scattered about; third article length two-thirds that of second, length 1.5 times width, short spiniform setae distally on inner and outer margins; fourth article short, extension for inner flagellum approximately equal to base, short spiniform seta near articulation with outer flagellum; outer flagellum short, with four to seven articles; when five-articulated first flagellar article length slightly greater than width, with small simple and pappose seta distally, second article length 1.2 times width, aesthetasc and several setae distally, third article length subequal to width, lacking setae, fourth article length about 1.5 times width, aesthetasc and two or three setae distally, fifth article with several terminal setae; inner flagellum extending to end of fourth article of outer flagellum, two-articulated, articles with two or three distal setae.

Antenna 2 (Fig. 8). Peduncle five-articulated, flagellum three- or four-articulated; first article wide, greatly expanded medially; second article long, length twice width, with two plumose setae on inner margin and plumose seta halfway on outer margin, spine-like projection

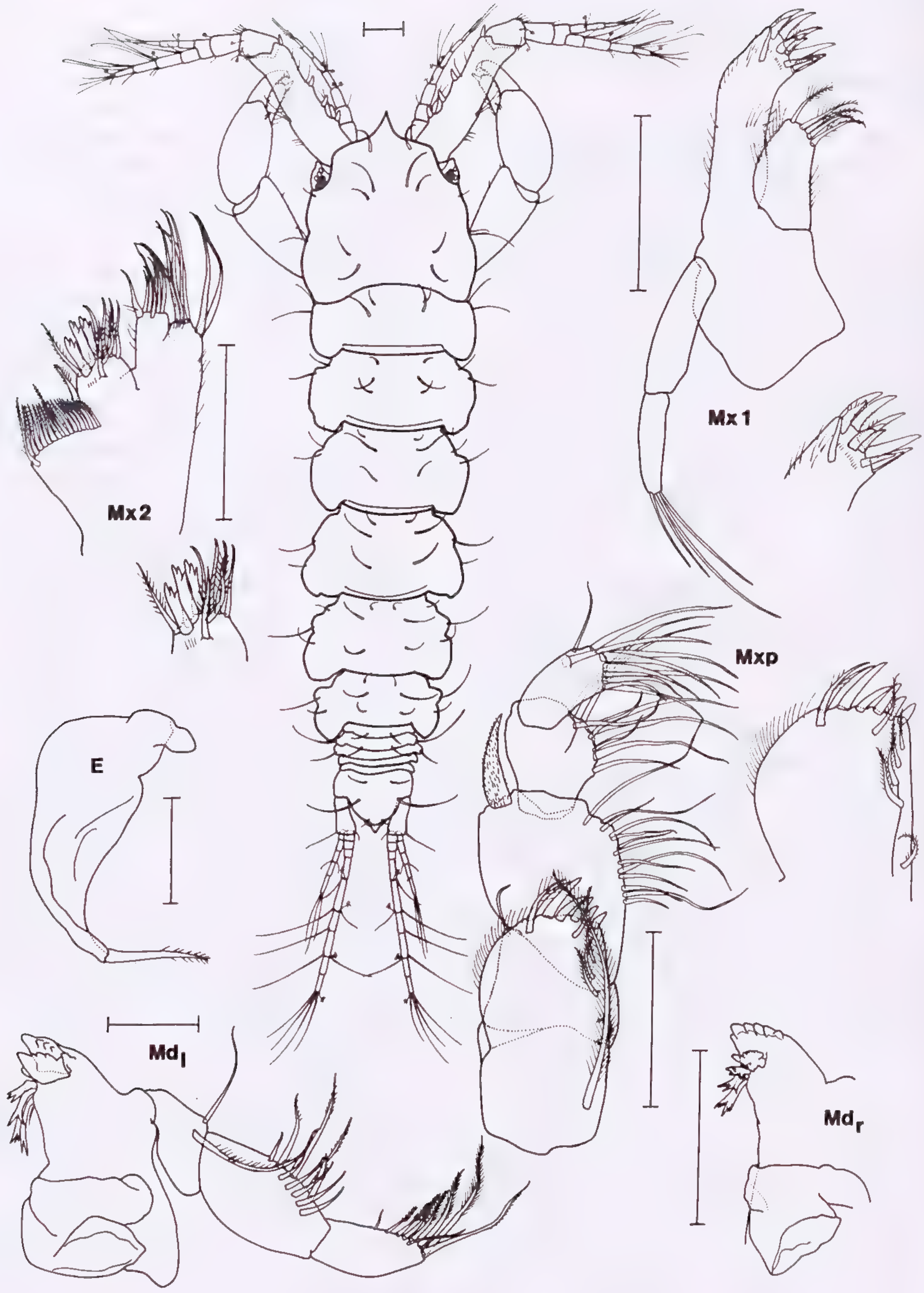

Fig. 7. *Apseudomorpha wagait* sp. nov., female: dorsal view of whole animal, left mandible (Md_l), right mandible (Md_r), maxilla 1 (Mx1), maxilla 2 (Mx2), epignath (E), maxilliped (Mxp). Whole animal drawn from holotype but with missing right cheliped added from paratype, mouthparts drawn from paratype. Scale bar = 0.1 mm.

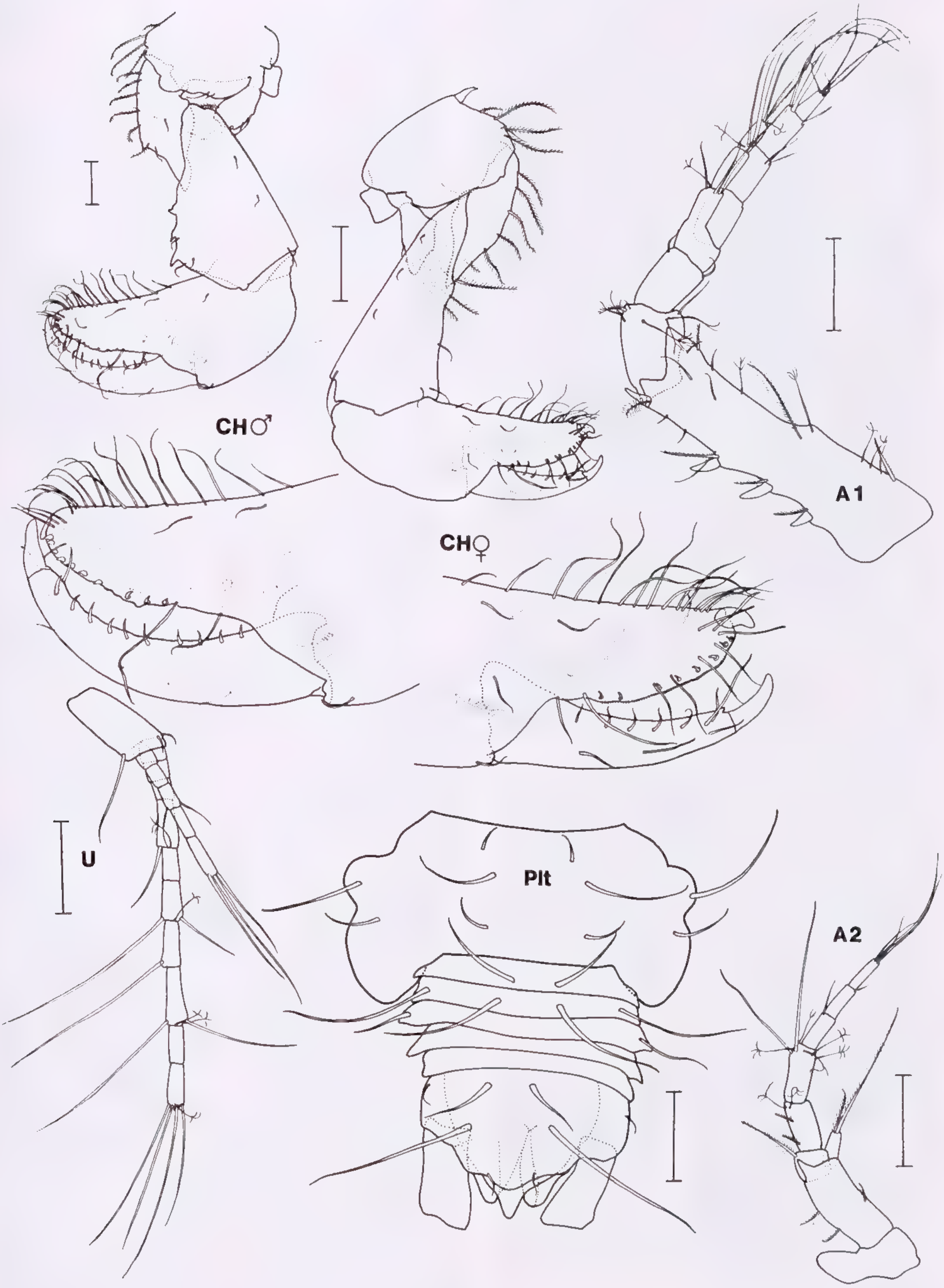

Fig. 8. *Apseudomorpha wagait* sp. nov., female paratype: antenna 1 (A1), antenna 2 (A2), cheliped (CH), pleotelson (Plt), uropod (U). Small cheliped (CH) of male paratype also included. Scale bar = 0.1 mm.

distally; scale elongate, three times as long as wide, with two very long plumose setae terminally; third article annular, length three-quarters width, with long distal plumose seta; fourth article nearly twice as long as wide with two plumose setae at one-third and two-thirds distance to end, two pappose setae distally; fifth peduncular article similar to fourth, pappose setae and two long simple setae distally; when flagellum three-articled, first flagellar article length 2.5 times width, single simple seta distally, second article similar to first but with slightly less width, third article length four times width, five to seven terminal setae.

Mandibles (Fig. 7). Molar process well developed with broad grinding area; palp three-articulated, first article triangular, with two long plumose setae at inner distal corner, second article with convex inner and outer margins, row of four or five long pectinate setae and adjacent row of six to eight simple setae in distal half near inner margin, third article with rounded outer and straight inner margins, row of six to eight pectinate setae of increasing size along distal half of inner margin, two long pectinate terminal setae; row of spiniform setae located on lobe, consisting of four strong denticulate setae; lacinia mobilis well developed on left mandible with four rounded teeth, reduced to stump on right mandible; incisor process with five rounded teeth.

Maxilla 1 (Fig. 7). Outer endite with eleven terminal spiniform setae including smaller central row of three, single subterminal spiniform seta, setules distally on outer margin, row of five to seven small simple setae midway on outer margin; inner endite leaflike, three or four plumose setae distally and slightly larger plumose seta terminally, setules along inner and outer margins; palp elongate, second article slightly shorter than first, with four long terminal setae.

Maxilla 2 (Fig. 7). First outer lobe with setules on outer edge, proximally with two long simple setae, distally with six or seven long terminal setae; second lobe with about eight setae; inner lobe proximally near inner edge with row of about 16 plumose setae and three larger plumose setae nearby; outer edge with three denticulate setae, three or four plumose setae and four simple setae.

Labium. Not observed.

Maxilliped (Fig. 7). Medially unfused; basis proximally with length equal to width, extremely large plumose seta attached proximally near inner margin; endite well developed, slightly longer than wide, with plumose seta attached proximally near inner margin, about five barbed setae distally near inner margin, about five or six spiniform setae along terminal margin, one subterminal and one inner distal plumose setae, setules distally along outer margin with two simple setae adjacent; palp four-articulated, first article short, expanded distally on outer side, second article widest distally, with extremely large, hirsute thorn-like seta on outer distal corner, numerous long setae along distal half of inner margin, third article distally expanded, slightly longer than wide, with about ten long setae along distal inner margin, fourth article three-quarters length of third article, terminating in about nine long finely-pectinate setae and a simple seta subterminally on outer margin.

Epignath (Fig. 7). Broad, cup-shaped; terminal projection length greater than width, hirsute distally; small rounded accessory lobe.

Cheliped (female) (Fig. 8). Basis with exopodite, ovate, about 1.7 times as long as wide, large spiniform seta two-thirds way along convex ventral margin, four large simple setae distally on ventral margin; exopodite club-shaped, two-articulated, first article small and square, second article distally expanded, four long plumose setae terminally and two short simple setae distally on dorsal margin; merus produced into large tooth distally, with five or six long plumose setae on ventral margin; carpus large, triangular, length twice width, with about three small simple setae near dorsal and ventral margins including one longer seta in each distal corner; propodus hand length 1.5 times width, two small pectinate setae adjacent to articulation with dactylus; propodus thumb length equal to hand, length about twice width, with row of about five setae along dorsal margin, row of about 15 setae along ventral margin, several small setae on sides, short, large terminal spiniform seta; dactylus smooth, about six small setae along ventral margin, claw length about one-fifth dactylus length.

Cheliped (male) (Fig. 8). Left and right chelipeds dissimilar in size, largest cheliped approximately evenly divided between left and right; small cheliped generally similar in proportions and setation to female cheliped but with wider carpus, ventral margin of carpus produced distally into three small irregular teeth,

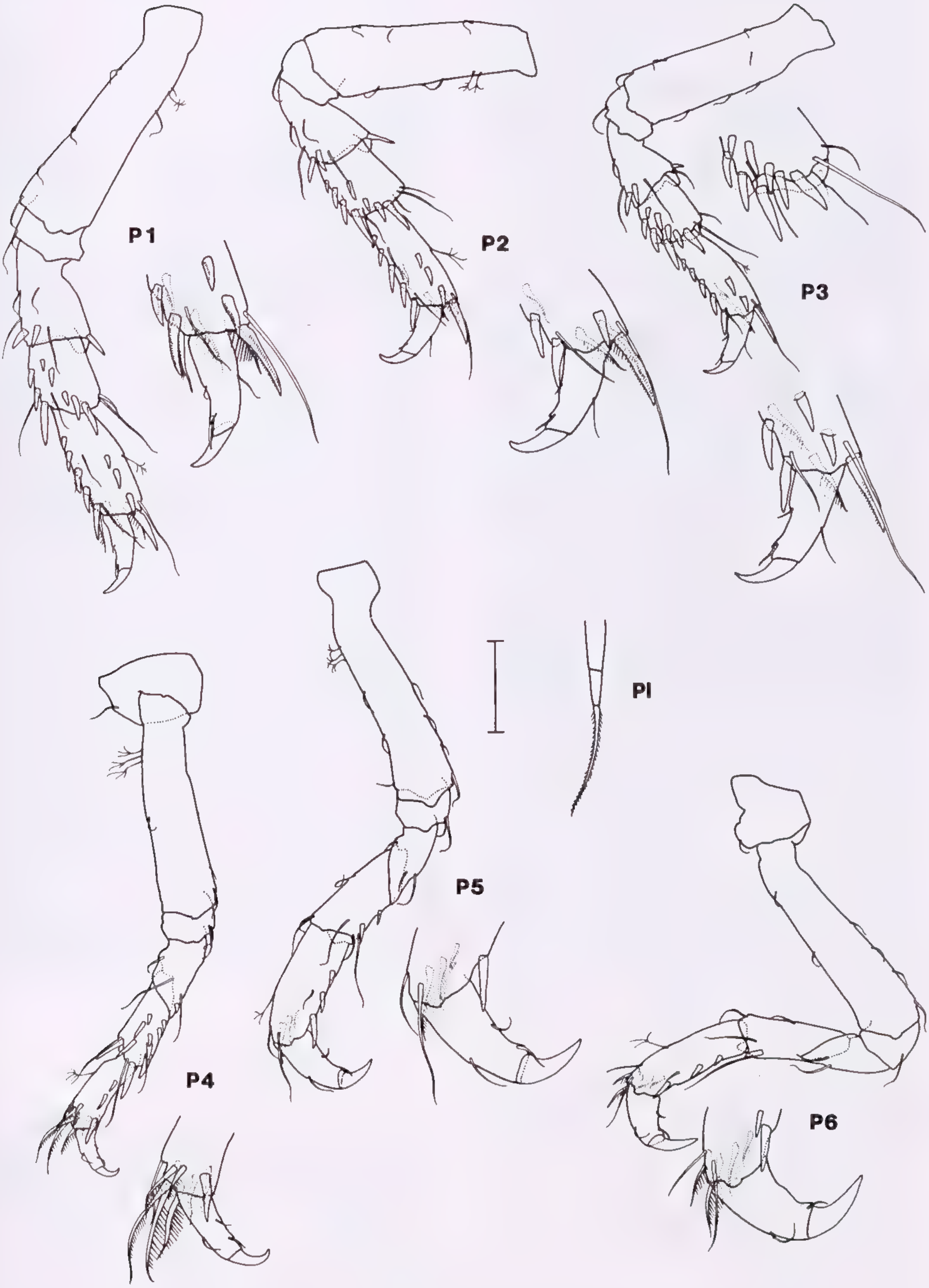

Fig. 9. *Apseudomorpha wagait* sp. nov., female paratype: pereopods 1 to 6 (P1-6), pleopod (Pl). Scale bar = 0.1 mm.

propodus short and wide, propodus hand length equal to width. Large cheliped with very large propodus and relatively small carpus, dactylus short and wide, upper margin of thumb and lower margin of propodus with large teeth.

Pereopods 1-3 (Fig. 9). Similar to each other, of walking type; basis quadrangular, about four times as long as broad, several small setae near dorsal and ventral margins, medium-sized seta distally on ventral margin, group of two or three plumose setae proximally on dorsal margin, exopodite absent on pereopod 1; ischium annular, about 2.5 times as wide as long, medium-sized seta distally on ventral margin; merus expanded distally, length about 1.5 times width, one spiniform seta distally on dorsal margin, one medium spiniform seta and one short spiniform seta distally near ventral margin, two setae midway along segment and two or three setae distally; carpus quadrangular, slightly shorter than merus, two rows of three to five spiniform setae near ventral margin with largest seta at distal end, about six setae distally; propodus slightly expanded distally, length about 1.5 times length of carpus, with row of five spiniform setae of increasing size along ventral margin, row of three or four spiniform setae of increasing size near dorsal surface culminating in long spiniform seta with adjacent simple seta next to articulation with dactylus, single pectinate seta midway and two pectinate setae distally along segment, pappose seta midway along dorsal margin; dactylus with large claw, hairs midway and at base of claw.

Pereopod 4 (Fig. 9). Similar in shape and armature to pereopods 1-3 except for more slender merus and carpus, additional large spiniform seta distally on carpus, additional two very long pectinate setae distally on propodus, lacking dorsal row of spiniform setae on propodus including very large spiniform seta beside articulation with dactylus.

Pereopod 5 (Fig. 9). Similar in shape and armature to pereopod 4 except for reduced spination, namely lacking distal spiniform seta on merus, possessing only two small spiniform setae on carpus, and only one very long seta distally on propodus.

Pereopod 6 (Fig. 9). Similar to pereopod 5 except lacking spiniform seta midway on ventral margin of carpus.

Pleopods (Fig. 9). Simple, uniramous, filiform, two-articulated, with long terminal plumose seta, three pairs present.

Uropods (Fig. 8). Biramous, filiform; peduncle about twice as long as wide, long seta distally on outer margin; endopodite relatively short, with about nine articles; first three articles short, length approximately equal to width, other articles long, generally two to three times as long as wide, with long simple setae and pappose setae distally on most articles; endopodite about two-fifths length of exopodite, four- or five-articulated, about three long simple setae terminally, second last article with one or two distal setae.

Etymology. The species name refers to a local aboriginal linguistic group.

Distribution. Darwin region, Australia; 2-8 m depth.

Remarks. *Apseudomorpha wagait* differs from other species in the genus because of the combination of pointed rostrum, uniramous pleopods, and lack of acute lateral projections on pleonites (see Gutu 1987). Numerous synapomorphies exist between *A. wagait* and *Pseudoapseudomorpha madagascariensis* Gutu, 1991, including general body shape, pointed rather than serrated rostrum, ladle-shaped epignath, antennae 1 with two- or three-articulated flagellum and spinous basis, antennae 2 with foliaceous elongation to basis, pereopods 1 and 2 approximately similar to each other, uniramous pleopods, uropods with eight- or nine-articulated exopodite and four- or five-articled endopodite (Gutu 1991). It differs in the arrangement of spiniform setae on the basis of antenna 1, by possessing a large denticulate rather than spiniform seta on the outer distal corner of article 2 of the maxilliped, by lacking tubercles on the pleotelson, and, most importantly, by possessing a palp on maxilla 1.

Apseudomorpha wagait is a cryptofaunal species that was collected almost exclusively from broken coral rubble.

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AN ANNOTATED CHECK-LIST OF THE CARIDEAN SHRIMPS (CRUSTACEA: DECAPODA) OF DARWIN HARBOUR, WITH DESCRIPTIONS OF THREE NEW SPECIES OF *PERICLIMENES* [PALAEMONIDAE: PONTONIINAE]

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ABSTRACT

The caridean shrimp fauna of Darwin Harbour, Northern Territory, Australia, is listed. 121 species are provisionally recognised and 108 are named, including three new species of the genus *Periclimenes* Costa (Pontoniinae). The presence of several further undescribed new species is also indicated. Nine families are represented by 36 genera. The Palaemonidae are represented by 13 genera with only 40 species, in contrast to the Alpheidae, which has only 7 genera, but with 55 species. The next most abundant family, the Hippolytidae, has an intermediate status, with 15 species of 10 genera. Seven species are recorded from Australian waters for the first time: *Macrobrachium equidens, Periclimenaeus crassipes, Periclimenes investigatoris, P. suvadivensis, Alpheus brevicristatus, A. serenei,* and *Athanas polymorphus*. Four families, the Pasiphaeidae, Anchistioididae, Ogyrididae and Pandalidae, are represented each by a single species only.

KEYWORDS: Faunistic survey; northern Australia; Darwin Harbour; Crustacea; Decapoda; Caridea; *Periclimenes;* Pontoniinae; new species.

"The point of cataloguing is that you cannot begin to answer questions about the nature of life or the resilience of the environment until you know what is there". (Robyn Williams, *A Promise of Miracles*, 1993).

INTRODUCTION

The study of the caridean shrimp fauna of Australia's northern shores has attracted little attention from the scientific community. The first record of shrimp from Darwin Harbour is that of Miers (1874) in his report on the zoological collection of HMS *Erebus* and HMS *Terror*, who listed the alpheid shrimp, *Alpheus edwardsii*, as the only caridean shrimp collected from this locality, although these vessels did not visit Darwin. The later visit by HMS *Alert* to the Northern Territory unfortunately did not extend to Darwin Harbour. The visit in 1889 by HMS *Beagle* did not produce any collection of crustacea. Subsequently, Elizabeth Pope (1949) also reported *A. edwardsii* from Darwin and later described the intertidal reefs at East Point (1967), but only mentioned the presence of unidentified alpheid shrimps. More recently Banner and Banner (1973a, 1976, 1982) recorded a further seven species of alpheid shrimp, largely from the collections of the Australian Museum, Sydney. Bruce (1979) described a new pontoniine shrimp that had been collected from Darwin Harbour in 1929.

More systematic studies commenced in 1981 with the establishment of the new Northern Territory Museum at Bullocky Point. It rapidly became evident that a rich caridean fauna was present in the Harbour, and several short papers described some of the new taxa, and Bruce (1983b) provided details of several species new to the Darwin Harbour fauna. The East Point Fish Reserve reefs attracted particular attention

In: Hanley, J. R., Caswell, G., Megirian, D. and Larson, H.K. (eds).*Proceedings of the Sixth International Marine Biological Workshop. The marine flora and fauna of Darwin Harbour, Northern Territory, Australia.* Museums and Art Galleries of the Northern Territory and the Australian Marine Sciences Association: Darwin, Australia, 1997:301–337.

and a report (Bruce 1988) recorded the presence of 65 mainly intertidal species at that restricted locality.

The present report up-dates and extends the East Point report and virtually doubles the number of caridean shrimp known from Darwin Harbour. Even so the fauna cannot be considered at all completely known. The fauna of the central deeper waters of the Harbour has scarcely been sampled and is largely unknown. The exact taxonomic status of several species remains to be fully established, although this will certainly be clarified by the studies of the alpheid shrimps by Dr Yukio Miya now in progress. Unfortunately large numbers of specimens of several families, particularly of Alpheidae, Hippolytidae, Processidae and Crangonidae, remain to be identified to species level. It is probable that these will include a number of additions to the fauna list and even new taxa. It seems likely that some 150 species could reasonably be expected to be present in Darwin Harbour.

SYSTEMATIC LIST

PASIPHAEIDAE Dana, 1852

Leptochela sydniensis Dakin and Colefax, 1940

Leptochela sydniensis Dakin and Colefax, 1940: 153, figs 245-246.

Previously reported from East Point (Bruce 1988), further material has now been collected from Channel Island. Also known extensively from New South Wales, Victoria, Tasmania, South Australia, and southern Western Australia. It is likely that further species of this genus are present in the unexamined material of this genus.

Distribution. Type locality: off Sydney, New South Wales. Also known from the Arabian Sea, Bay of Bengal, South China Sea, East China Sea and Japan.

PALAEMONIDAE Rafinesque, 1815

Palaemoninae Dana, 1852

Leandrites celebensis De Man, 1881

Leander celebensis De Man, 1881: 141.

Leandrites celebensis – Holthuis 1950: 35-37, fig. 4.

First reported in Australia from Woods Inlet, Darwin Harbour (Bruce 1986a) and since recorded from Groote Eylandt. Also now known from Cameron Beach, Ludmilla Creek, Buffalo Creek, Shoal Bay, Woods Inlet, Channel Island, and mouth of the Blackmore River. Not recorded from elsewhere in Australia.

Distribution. Type locality: Ujung Pandang, Indonesia. Also known from India, Singapore and Java.

Macrobrachium equidens (Dana, 1852)

Palaemon equidens Dana, 1852a: 26.

Macrobrachium equidens – Holthuis 1950: 162-172, fig. 36.

New to the Northern Territory. Not previously recorded from Australian waters. Specimens identified by John Short, Queensland Museum, have been collected from Cameron Beach, Bullocky Point, Ludmilla Creek, Mickett Creek, Kings Creek, Comalie Creek, Shoal Bay, Leader's Creek, and Channel Island.

Distribution. Type locality: Singapore. Also known from East Africa to the Ryukyu Islands, including Indonesia and Papua-New Guinea, east to New Britain and New Caledonia.

Palaemon macrodactylus Rathbun, 1902

Palaemon macrodactylus Rathbun, 1902: 52, fig. 24.

Not previously reported from the Northern Territory, specimens have been collected from Channel Island and the mouth of the Blackmore River. Also known in Australia from South Australia and New South Wales (Holthuis 1980), this species is probably an immigrant species from eastern Asia (Newman 1963).

Distribution. Type locality: type material described from Aomori, Matsushima, Nagasaki, Japan; Fusan, Gensan, China, and Chemulpo, Korea. Also recently reported from San Francisco, California.

Palaemon semmelinkii (De Man, 1881)

Leander semmelinkii De Man, 1881: 137.

Palaemon (Paleander) semmelinkii Holthuis 1950: 59-60, fig. 11.

Not previously recorded from Darwin Harbour, specimens have been collected from Channel Island, mouth of the Blackmore River, and Gunn Point. Also known from Groote Eylandt, Gulf of Carpentaria (Bruce 1986a), and the Cobourg Peninsula (Bruce and Coombes 1995). No further records from Australian waters.

Distribution. Type locality: Ujung Pandang, Indonesia. Also known from India, Burma, Nicobar Islands, Singapore and the Philippines.

Palaemon serrifer (Stimpson, 1860)

Leander serrifer Stimpson, 1860: 41.
Palaemon serrifer – Rathbun 1902: 52.

Previously reported from Bullocky Point (Bruce 1986a) and noted as common in Darwin Harbour (Bruce 1988). Specimens also collected from Casuarina Beach, Channel and Shell Islands. Also known from Port Essington, Cobourg Peninsula. Not yet recorded elsewhere in Australia.

Distribution. Type locality: Hong Kong. Also known from India to Indonesia and Japan.

Urocaridella antonbruunii (Bruce, 1967)

Periclimenes antonbruunii Bruce, 1967: 45-53, figs 19-22.
Leandrites cyrtorhynchus Fujino and Miyake, 1969: 143-149, figs 1-3.
Urocaridella antonbruunii – Chace and Bruce 1993: 42.

Previously recorded from Six Mile Buoy, Darwin Harbour (Bruce 1983b) at 12 m, the specimen engaged in fish-cleaning behaviour, and now also known from Channel Island and the East Arm of Darwin Harbour, and the Cobourg Peninsula (Bruce and Coombes 1995). Also known from Heron Island, Queensland. Now well known as a fish cleaner.

Distribution. Type locality: Pamanzi Island, Mayotte, Comoro Islands. Also recorded from Kenya, Japan, New Caledonia and Marshall Islands.

Urocaridella sp.

Urocaridella sp. Bruce, 1993a: 36, col. fig.; 1995.

Previously recorded from Darwin Harbour (Bruce 1993a), this taxon appears only distinguishable from *U. antonbruunii* by its consistently different colour pattern in life. Also known from Port Essington, Cobourg Peninsula.

Pontoniinae Kingsley, 1878

Anchistus custos (Forsskål, 1775)

Cancer custos Forsskål, 1775: 94.
Anchistus custos – Holthuis 1952: 105-109, figs 83-84.

Previously reported from East Point (Bruce 1988), now known also from Channel Island, Weed Reef and Fannie Bay, and also reported from Port Essington, Cobourg Peninsula, Northern Territory. Known from Western Australia, Queensland and South Australia. Associated with pinnid bivalves.

Distribution. Type locality: Al Luhayyah, Yemen. Widespread throughout most of the Indo-West Pacific region, from the northern Red Sea east to the Caroline and Solomon Islands.

Hamodactylus boschmai Holthuis, 1952

Hamodactylus boschmai Holthuis, 1952: 209-212, figs 102-104.

Previously reported from East Point (Bruce 1988) and now also known from Weed Reef. Also known from the Cobourg Peninsula, Northern Territory, and Heron Island, Queensland.

Distribution. Type localities: Ternate and Aru Islands, Indonesia. Also known from Zanzibar, Kenya, Madagascar, Singapore, Hong Kong and New Caledonia.

Hamopontonia corallicola Bruce, 1970

Hamopontonia corallicola Bruce, 1970a: 41-48, figs 1-4.

Previously reported from East Point (Bruce 1988), no further specimens have been obtained from Darwin Harbour. Also known from Coral Bay, Port Essington (Bruce 1986b). Recorded from Peloris and Heron Islands, Queensland.

Distribution. Type locality: Kat O Chau, Hong Kong. Otherwise known only from Indonesia, Japan, the Ryukyu Islands and Indonesia.

Ischnopontonia lophos (Barnard, 1962)

Philarius lophos Barnard, 1962: 242-243, fig. 2.
Ischnopontonia lophos – Bruce 1966: 585-595, figs 1-5.

Previously reported, from a single chela from *Galaxea*, from East Point (Bruce 1983a, 1988), and now also known from Channel Island. Also recorded from the Cobourg Peninsula. Reported from Great Palm, Orpheus, Fantome, Heron and One Tree Islands, Queensland. Associated with the oculinid coral *Galaxea fascicularis*.

Distribution. Type locality: Inhaca Island, Moçambique. Also known from Kenya, Zanzibar, Tanganyika, Comoro Islands, Madagascar, Seychelle Islands, La Réunion, Singapore, Malaya, Caroline Islands, Fijian Islands and Ryukyu Islands.

Palaemonella pottsi (Borradaile, 1915)

Periclimenes (Falciger) pottsi Borradaile, 1915: 212.

Palaemonella pottsi — Kemp 1922: 126-127.

Previously reported from East Point (Bruce 1988). Also known from the Cobourg Peninsula, Northern Territory, Thursday Island, Heron and One Tree Islands, Queensland. An associate of crinoids.

Distribution. Type locality: Mabuaig, Murray Island, Queensland. Also known from the Red Sea(?), Kenya, Zanzibar, Singapore, Indonesia, Japan, the Philippines, New Caledonia and Marshall Islands.

Palaemonella rotumana (Borradaile, 1898)

Periclimenes rotumanus Borradaile, 1898: 383.

Palaemonella rotumana — Bruce 1970c: 276-279, pl. 1e-f.

Previously reported from Darwin Harbour (Bruce 1983b, 1986, 1987a) and from East Point, (Bruce 1988). Also reported from Rottnest Island, Western Australia, the Cobourg Peninsula, Northern Territory, and the Herald Islands, Low Isles, Heron Island, One Tree Island, and Moreton Bay, Queensland.

Distribution. Type locality: Rotuma Island. Widely distributed from the northern Red Sea to Moçambique, east to the Fijian Islands and Hawaii, north to Japan, south to New Caledonia, also in the Eastern Mediterranean Sea.

Palaemonella spinulata Yokoya, 1936

Palaemonella spinulata Yokoya, 1936: 135, fig. 4.

Previously reported from the Cobourg Peninsula, Northern Territory, only one specimen has been collected from Fannie Bay, at 8-10 m. Also reported from Heron Island and Moreton Bay, Queensland.

Distribution. Type locality: Misaki, Japan. Otherwise known only from Kenya, Tanganyika and La Réunion.

Periclimenaeus bidentatus Bruce, 1970

Periclimenaeus bidentatus Bruce, 1970b: 305-307.

Not previously recorded from Darwin Harbour. Two lots of specimens have been collected from Weed Reef, one lot from a sponge host, *Hyatella intestinalis*, from 8-10m. Also known from Heron Island and Moreton Bay, Queensland. Associated with sponges.

Distribution. Type locality: Heron Island, Queensland. Also known from Kenya, Zanzibar, Hibernia Reef, Timor Sea and New Caledonia.

Periclimenaeus crassipes (Calman, 1939)

Periclimenes (Ancyclocaris) crassipes Calman, 1939: 211-215, fig. 5.

Not previously recorded from Australian waters, this species is known only from the type specimens collected sixty years ago in 1933 by HMS *Mabahiss*, during the John Murray Expedition (Calman 1939). The ovigerous female specimen has a carapace length of 3.5 mm and rostral dentition of 4/0, like the holotype female. The specimen (NTM Cr.000326) was obtained from 8-10 m at East Point, in an ascidian, *Didemnum psammatoides*.

Distribution. Type locality: off Oman, 18°03.5'N, 57°02.5'E, at 38 m. No other records.

Periclimenaeus tuamotae Bruce, 1969

Periclimenaeus tuamotae Bruce, 1969b: 170-172.

Not previously reported from Darwin Harbour. One lot of specimens (NTM Cr.001605) has been collected from an unidentified sponge host from East Point at 10 m. Also known from Heron Island, Queensland.

Distribution. Type locality: Mururoa Atoll, Tuamotu Islands. Also known from Kenya, and from Tanganyika(?).

Periclimenaeus sp. nov.

Three specimens (NTM Cr.003307) have been collected from unidentified sponges from 3-5 m at Woods Inlet. These will be described in a subsequent publication.

Periclimenella spinifera (De Man, 1902)

Periclimenes Petitthouarsi var. *spinifera* De Man, 1902: 824.

Periclimenella spinifera – Duris and Bruce 1995: 656-661, figs 19-20.

Previously reported from East Point (Bruce 1983b, 1988), further specimens have been collected at East Point and also from Channel Island. Common in shallow water on the Cobourg Peninsula. Also known from Lizard

Island, Northwest and Low Islands, Heron and One Tree Islands, Queensland. One of the commonest coral reef shrimps, often found in branching corals or freely in reef pools.

Distribution Type locality: Ternate, Ambon, Indonesia. Also known from Madagascar to Tahiti and Wake Island, north to the Ryukyu Islands, but absent from the north west Indian Ocean and Red Sea.

Periclimenes albolineatus sp. nov.

(Figs 1-2)

Material examined. HOLOTYPE, 1 non-ovig. ♀, PARATYPE, 1 juv. ♀, Lee Point, Darwin Harbour, 12°19.0'S, 130°52.5'E, ELWST, coll. J.R. Hanley, NTM Cr.000134.

Description. A small sized moderately robust *Periclimenes* species, of subcylindrical body form.

Rostrum (Fig. 2b,c) slender, straight, horizontal, about 0.55 of carapace length (Figs 1a, 2a), reaching to about middle of intermediate segment of antennular peduncle, with five (female) (Fig. 2b) or six (ovigerous female) (Fig. 2c) acute evenly spaced dorsal teeth, first tooth situated on carapace, distinctly posterior to orbital margin, at or posterior to level of hepatic spine, distal tooth in larger female reduced, lateral carinae obsolete, ventral carina obsolete, margin convex, unarmed, with short plumose median setae proximally. Carapace (Figs 1a, 2a) smooth, glabrous, without epigastric tubercle, epigastric and supraorbital spines absent, orbit feebly developed, inferior orbital angle feebly produced, rounded, antennal spine well developed, marginal, far exceeding inferior orbital angle, hepatic spine subequal to antennal spine, posterior to antennal spine at slightly lower level, anterior to level of first dorsal rostral tooth, anterolateral angle of branchiostegite bluntly obtuse, feebly produced.

Abdomen smooth, glabrous, third tergite not posterodorsally produced, pleura broadly rounded, sixth segment about 1.7 times length of fifth, 1.45 times longer than deep, 0.55 of carapace length, posteroventral angle bluntly produced, posterolateral angle acutely produced. Telson (Fig. 1m) about 1.3 times sixth segment length, 3.2 times longer than anterior width, lateral margins with distal two thirds convergent, with two pairs of small submarginal, dorsal spines, at 0.65, 0.8 of length, posterior margin (Fig. 2i) about 0.4 of anterior width, angular, centrally produced, without median point, lateral spines subequal to dorsal spines, subdorsal, intermediate spines stout, blunt, about 0.12 of telson length, submedian spines slender, setulose, about 0.7 of intermediate spine length.

Antennular peduncle (Fig. 1c) normal, proximal segment about 2.3 times longer than central width, with ventromedial tooth, distolateral angle acutely produced, with strong acute lateral tooth, statocyst with granular statolith, stylocerite slender, acute, reaching to about 0.5 of segment length, intermediate and distal segments normal, combined lengths about 0.75 of proximal segment length, upper flagellum with proximal four segments of rami fused, shorter free ramus with two segments, with 10 groups of aesthetascs, longer ramus and lower flagellum slender, filiform.

Antenna (Fig. 1d) with basicerite with feeble lateral tooth, carpocerite subequal to proximal segment of antennular peduncle, about 2.6 times longer than central width, reaching to about 0.5 of scaphocerite length, flagellum well developed; scaphocerite about 2.7 times longer than central width, lateral margin straight with strong distolateral tooth, lamella broad, slightly tapering, distally bluntly angular, far exceeding distolateral tooth.

Eye (Fig. 1b) with large globular cornea, about 0.14 of carapace length, with dorsal accessory pigment spot, stalk about 1.35 times longer than wide, 1.5 times longer than corneal diameter.

Mouthparts not dissected, of normal *Periclimenes* form. Fourth thoracic sternite without median process, with short, low, lateral, transverse ridges.

First pereiopods slender (Fig. 1e), merus reaching to distal end of carpocerite, chela (Fig. 2d) with palm subcylindrical about 2.5 times longer than deep, fingers slender, compressed, about 0.75 of palm length, tips acute, strongly hooked, densely setose, ungues not distinctly articulated, cutting edges well developed, entire, laterally situated, with distinct distal tooth, setae along inner margin of cutting edge short, blunt distally, without disto-anterior denticles; carpus about 1.4 times chela length, subcylindrical, about 7.5 times longer than distal width; merus subequal to carpus, uniform, 7.5 times longer than central width; ischium about 0.6 of merus length; basis normal; coxa with small ventral lobe.

Second pereiopods similar, moderately unequal (Fig. 1fi); major chela (Fig. 1g) about 1.1

times carapace length, palm subcylindrical, slightly compressed, smooth, about 4.0 times longer than central width, slightly swollen centrally, fingers (Fig. 1h) robust, about 0.4 of palm length, dactyl about 3.0 times longer than deep, cutting edge with single strong acute tooth at about 0.33 of length, distal cutting edge entire, sharp, markedly concave, fixed finger similar, with two small acute teeth proximally, subequal, similar, cutting edge distally sharp.

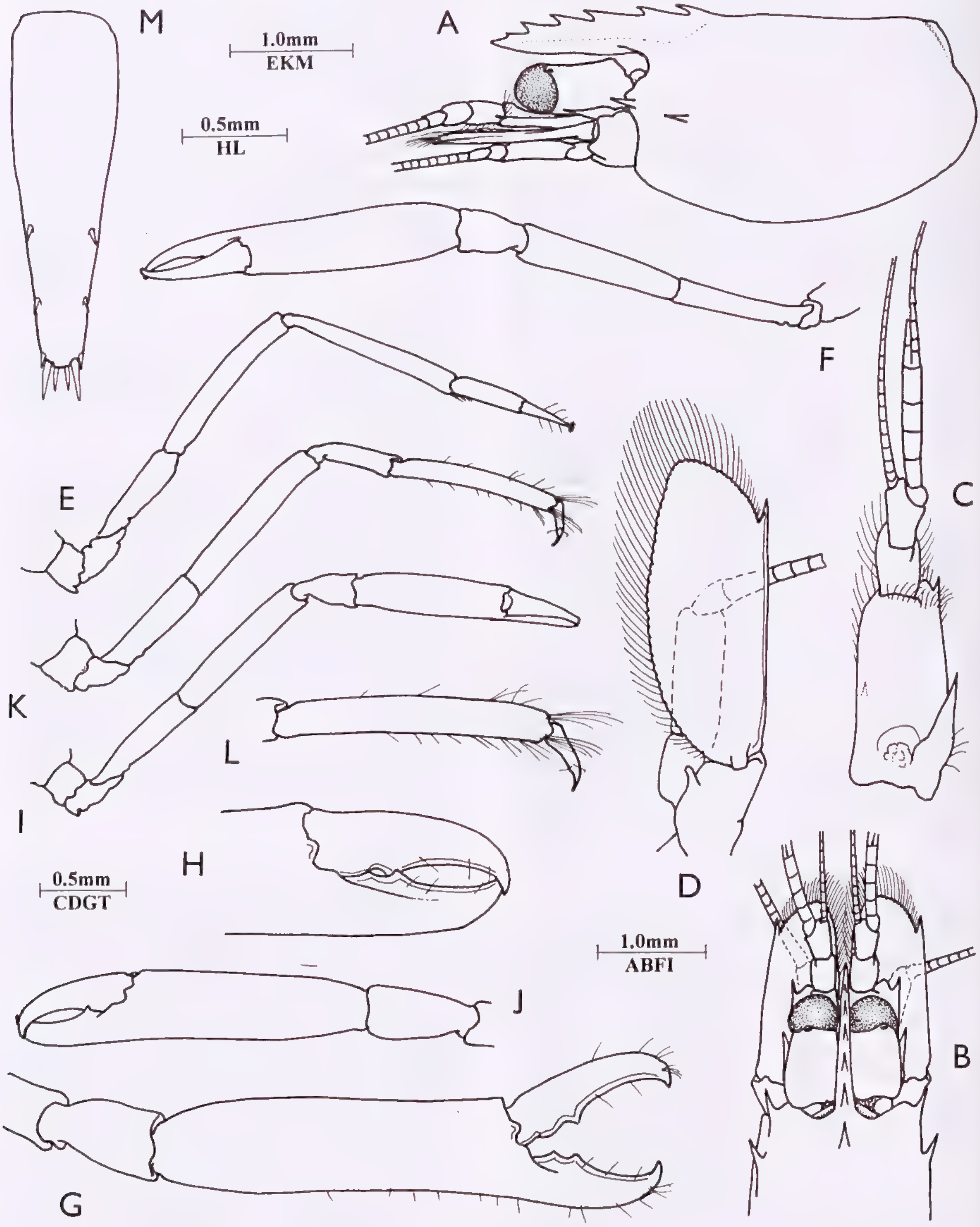

Fig. 1. *Periclimenes albolineatus* sp. nov., female holotype, Lee Point, Darwin Harbour. **A**, carapace, eye and antennal peduncles. **B**, anterior carapace, eyes and antennal peduncles, dorsal. **C**, antennule. **D**, antenna. **E**, first pereiopod. **F**, major second pereiopod. **G**, same, chela. **H**, same, fingers. **I**, minor second pereiopod. **J**, same, chela. **K**, third pereiopod. **L**, same, propod and dactyl. **M**, telson.

entire, concave, carpus about 0.33 of palm length, 1.7 times longer than distal width, tapering proximally, unarmed; merus about 0.7 of palm length, unarmed, 4.5 times longer than distal width, tapering slightly proximally; ischium about 0.8 of merus length, 5.2 times longer than distal width; basis and coxa without special features. Minor chela (Fig. 1j) about 0.8 of carapace length, 0.7 of the major chela length; subequal to major chela palm length, palm about 3.5 times longer than central width, tapering gradually proximally, fingers about 0.5 of palm length, similar to major chela, tip with strong, not distinctly articulated unguis; carpus about 0.45 of palm length; proximal segments similar to major chela.

Ambulatory pereiopods slender; third pereiopod (Fig. 1k) with dactyl slender, about 2.5 of propod length (Fig. 2h), simple, corpus about 2.0 times longer than proximal depth, compressed, tapering distally, dorsal margin convex, ventral margin concave, unguis distinctly demarcated, strong, curved, about 0.5 of corpus length; propod (Fig. 1L) about 0.5 of carapace length, 7.5 times longer than central depth, uniform, sparsely setose, without ventral or distoventral spines, with short transverse rows of long simple setae ventromedially and ventrolaterally, carpus 0.5 of propod length, unarmed; merus subequal to propod length, unarmed; ischium 0.7 of propod length, unarmed, basis and coxa normal; fourth and fifth pereiopods similar to third.

Uropod (Fig. 2j) with protopod with small blunt distolateral lobe; exopod about 3.0 times longer than wide, lateral margin with slender acute distolateral tooth (Fig. 2k), with longer mobile spine medially, dieresis well marked; endopod subequal to exopod length, about 4.0 times longer than wide.

Measurements (mm). Holotype female, carapace length, 2.6; carapace and rostrum, 4.0;

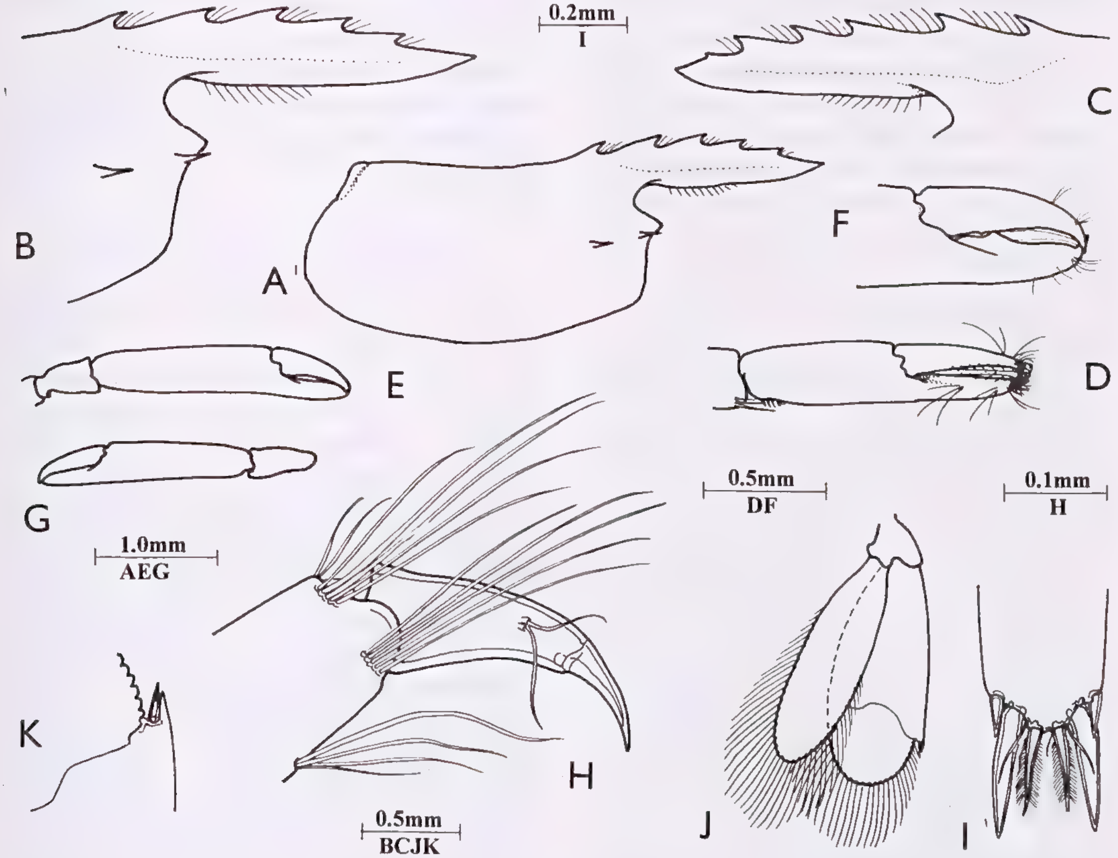

Fig. 2. *Periclimenes albolineatus* sp. nov., Lee Point, Darwin Harbour. **A**, carapace and rostrum. **B**, anterior carapace and rostrum. **C**, rostrum. **D**, first pereiopod, chela. **E**, major second pereiopod, carpus and chela. **F**, same, fingers. **G**, minor second pereiopod, carpus and chela. **H**, third pereiopod, distal propod and dactyl. **I**, posterior telson spines. **J**, uropod. **K**, same, distolateral angle of exopod. **A,B, E,F,G**, paratype female; **C,D,H,I,J,K**, holotype female.

total body length, (approx.), 12.6; second pereiopod, major chela, 2.9; minor chela, 2.2.

Host. Actinaria *indet.*

Colouration. Mainly transparent. Antennal peduncles and scaphocerite speckled with red, flagella colourless; ophthalmic segment with transverse white bar, eye with white dorsal stripe; carapace with long transverse mid-dorsal bar, speckled with red; rostrum colourless; abdomen with double white bars, with less marked intermediate bar, across first to third segments ventrally, finely speckled with red between white bars, pleura speckled with red, posterior segments and caudal fan colourless, ovary olive green, speckled with red; second pereiopod chelae with fingers colourless, palm with white spots and smaller red dots, carpus similar, less marked; ambulatory pereiopods feebly ringed or mottled with white.

Etymology. From *albus*, Latin, white, and *lineatus*, Latin, lined.

Systematic position. *Periclimenes albolineatus* is clearly a member of a group of closely related species, all associated with actinarian hosts: *Periclimenes brevicarpalis* (Schenkel*)*, *P. inornatus* Kemp, *P. ornatus* Bruce, and *P. ornatellus* Bruce, all of which have characteristic colour patterns in life. *Periclimenes brevicarpalis* and *P. albolineatus* have the fingers of the first pereiopod chelae simple. The three other species have these fingers distinctly subspatulate. *Perclimenes ornatellus* also differs from *P. albolineatus,* as well as *P. ornatus and P. inornatus* in the presence of numerous small microspinules on the unguis of the dactyl of the ambulatory pereiopods.

The most conspicuous difference between *P. albolineatus* and *P. brevicarpalis* is in the fingers of the major second pereiopod chela, in which the cutting edges gape widely distally when closed in the former species, but not in the latter. The fingers are also much shorter, about 0.5 of the palm length in *P. albolineatus*, but near subequal to the palm length in *P. brevicarpalis*, in which several small acute teeth are usually present. In *P. brevicarpalis* the rostrum usually reaches to or near to the distal margin of the antennular peduncle and bears one or two ventral teeth, with the first dorsal tooth situated over, or immediately posterior to the level of the posterior orbital margin, if not more anteriorly, unlike *P albolineatus*, in which it is much shorter, with the first dorsal tooth distinctly posterior to the posterior orbital margin, and without ventral teeth.

Periclimenes alegrias Bruce, 1986

Periclimenes alegrias Bruce, 1986b: 143-151, figs 1a, 2-5, 15a-c.

Previously reported from East Point (Bruce 1988). No further specimens have been subsequently collected. An associate of crinoid hosts, this species is only otherwise known from Arnhem Land.

Distribution. Type locality: Port Essington, Cobourg Peninsula. Not known from outside Australian waters.

Periclimenes amymone De Man, 1902

Periclimenes amymone De Man, 1902: 829-833, pl. 25, fig. 25.

Previously known from two specimens from *Acropora* from East Point (Bruce 1983b, 1988), there have been no further reports of this species from Darwin Harbour. Abundant in corals in Port Essington. Also known from the Coral Sea reefs, Heron Island and One Tree Islands, Queensland, and from Rottnest Island, Western Australia.

Distribution. Type locality: Ternate, Indonesia. Also known from the Nicobar Islands, Singapore, Vietnam, Indonesia, Papua-New Guinea, Solomon Islands, the Philippines and New Caledonia.

Periclimenes brevicarpalis (Schenkel, 1902)

Ancylocaris brevicarpalis Schenkel, 1902: 563, pl. 13, fig. 21.

Periclimenes (Ancylocaris) brevicarpalis Kemp, 1922: 185-191, figs 40-42, pl. 6, fig. 8.

Previously recorded from East Point (Bruce 1988), there have been no further reports of this species. Also known from the Monte Bello Islands, Western Australia; Port Essington, Northern Territory, Murray Island, Low Island, Port Denison, Magnetic Island and Heron Island, Queensland, and from Hibernia Reef, Timor Sea. Associated with Actinaria.

Distribution. Type locality: Ujung Pandang, Sulawesi, Indonesia. Also known from Aqaba, the Red Sea, Jibuti, Persian Gulf, Kenya, Zanzibar, Tanganyika, Moçambique, Madagascar, Mauritius, Seychelle Islands, Maldive Islands, south India, Andaman Islands, Malaya, Singapore, Vietnam, Hong Kong, South China Sea, Hainan Island, Ryukyu Islands, Japan, Indonesia, the Philippines, Papua-New Guinea, Solomon Islands, New Caledonia, Caroline Islands and Marshall Islands.

Periclimenes canalinsulae sp. nov.
(Figs 3-4)

Material examined. HOLOTYPE, 1♂, stn AJB-28, Channel Island, 12°33.4'S, 130°52.3E, 17 October 1985, ELWS, reef flat pool, coll. A.J.Bruce, rotenone, NTM Cr.003265.

Description. A small sized, slender *Periclimenes* species, of subcylindrical body form.

Rostrum (Fig. 3b) slender, straight, horizontal, about 0.7 of carapace length, reaching almost to distal end of intermediate segment of antennular peduncle, with five acute evenly spaced dorsal teeth, first tooth situated posterior to orbital margin, lateral carinae obsolete, ventral carina obsolete, margin convex, unarmed, with short plumose median setae proximally. Carapace (Fig. 3a) smooth, glabrous, with small epigastric tubercle, epigastric and supraorbital spines absent, orbit feebly developed, inferior orbital angle strongly produced, subacute, antennal spine well developed, marginal, exceeded by inferior orbital angle, hepatic spine subequal to antennal spine, posterior to antennal spine, anterior to level of first dorsal rostral tooth, anterolateral angle of branchiostegite bluntly obtuse, not produced.

Abdomen smooth, glabrous, third tergite not posterodorsally produced, pleura broadly rounded, sixth segment about 1.5 times length of fifth, 1.5 times longer than deep, 0.6 of carapace length, posteroventral angle bluntly produced, posterolateral angle acutely produced. Telson (Fig. 3m) about 1.2 times sixth segment length, 3.5 times longer than anterior width, lateral margins straight, convergent, with two pairs of small, marginal dorsal spines, at 0.6, 0.8 of length, posterior margin (Fig. 4q) about 0.33 of anterior width, angular, centrally produced, without median point, lateral spines subequal to dorsal spines, subventral, intermediate spines stout, blunt, about 0.12 of telson length, submedian spines slender, setulose, about 0.7 of intermediate spine length.

Antennular peduncle (Fig. 3c) normal, proximal segment about 2.3 times longer than central width, without ventromedial tooth, distolateral angle (Fig. 4a) acutely produced, with strong acute lateral tooth, statocyst with granular statolith, stylocerite slender, acute, reaching to about 0.5 of segment length, intermediate and distal segments normal, combined lengths about 0.75 of proximal segment length, upper flagellum with proximal four segments of rami fused, shorter free ramus with four segments, with 13 groups of aesthetascs, longer ramus and lower flagellum slender, filiform.

Antenna (Fig. 3d) with basicerite with feeble lateral tooth, carpocerite exceeding proximal segment of antennular peduncle, about 2.5 times longer than central width, reaching to about 0.6 of scaphocerite length, flagellum well developed; scaphocerite about 3.4 times longer than central width, lateral margin straight with strong distolateral tooth, lamella broad, scarcely tapering, distally bluntly angular, far exceeding distolateral tooth (Fig. 4b).

Eye (Fig. 3e) with large globular cornea, about 0.2 of carapace length, with dorsal accessory pigment spot, stalk about 1.2 times longer than wide, 1.2 times longer than corneal diameter.

Mouthparts of normal *Periclimenes* form; mandible without palp, molar process obliquely truncate distally, incisor process with three small acute teeth; maxillular palp bilobed; maxilla (Fig. 4c) with bilobed basal endite; first maxilliped (Fig. 4d) with basal and coxal endites fused, epipod small, bilobed; second maxilliped with small suboval epipod; third maxilliped (Fig. 4e) with ischiomerus and basis fused, terminal segment of endopod with long stout serrulate preterminal spine, without arthrobranch.

First pereiopods slender (Fig. 3f), merus reaching to distal end of carpocerite, chela (Fig. 4f) with palm subcylindrical about 3.0 times longer than deep, fingers slender, compressed, about 0.7 of palm length, tips acute, strongly hooked, ungues distinctly articulated, cutting edges well developed, entire, laterally situated, with distinct distal tooth (Fig. 4g), setae along inner margin of cutting edge short, blunt distally, with disto-anterior denticles (Fig. 4h); carpus about 1.6 times chela length, subcylindrical, about 8.5 times longer than distal width; merus slightly shorter than carpus, uniform, 9.0 times longer than central width; ischium about 0.6 of merus length; basis normal; coxa with small ventral lobe.

Second pereiopods similar, slightly unequal (Fig. 3g-i); major chela (Fig. 3h) about 0.8 of carapace length, palm subcylindrical, slightly compressed, smooth, about 4.3 times longer than distal width, tapering gradually proximally, fingers (Fig. 4i) robust, about 0.4 of palm length, dactyl with tip missing, about 3.5 times longer than deep, cutting edge with single small acute, recurved tooth at about 0.33 of length, distal cutting edge lateral, entire, sharp, fixed finger

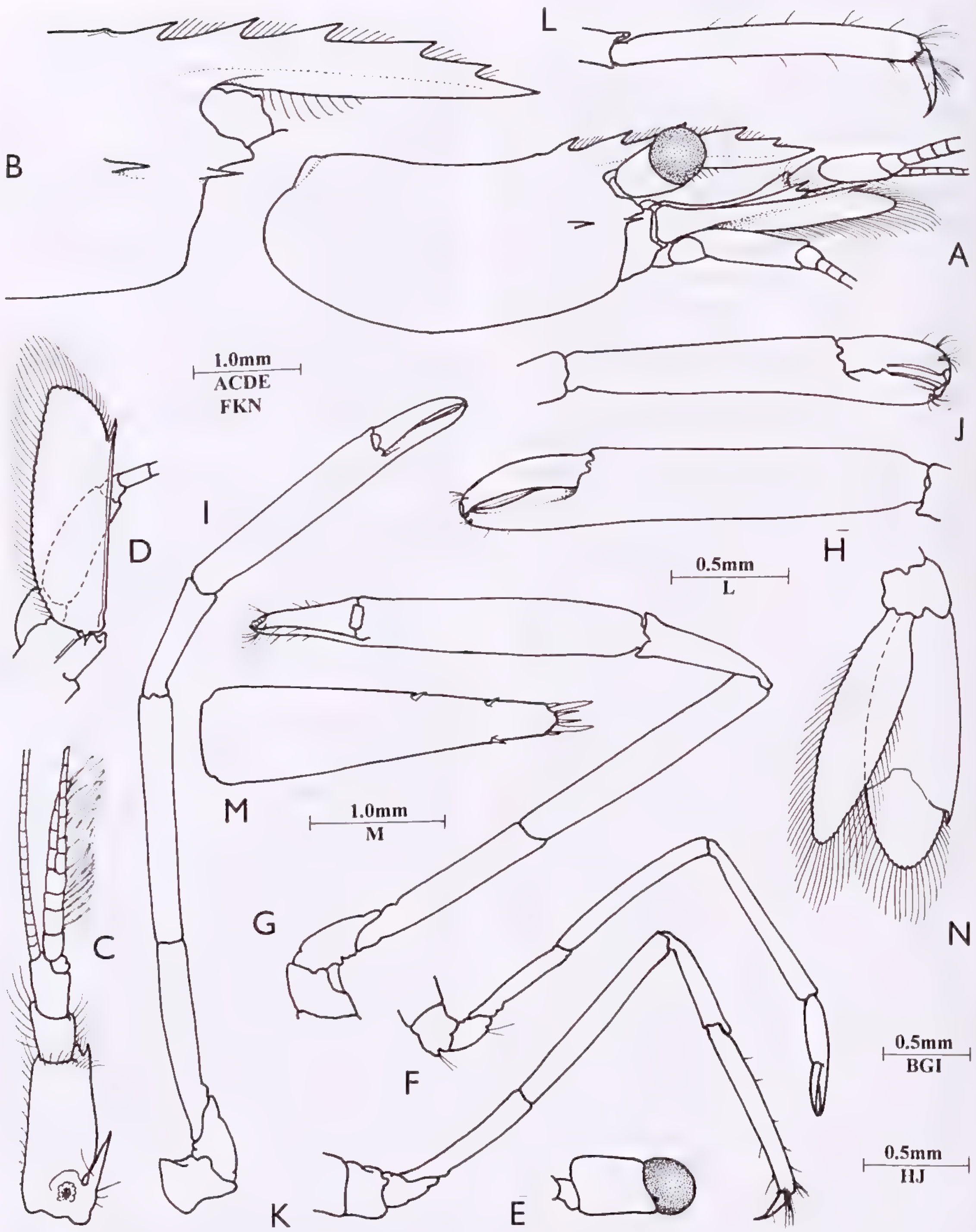

Fig. 3. *Periclimenes canalinsulae* sp. nov., holotype male, Channel Island, Darwin Harbour. **A**, carapace, eye and antennal peduncles. **B**, anterior carapace and rostrum. **C**, antennule. **D**, antenna. **E**, eye, dorsal. **F**, first pereiopod. **G**, major second pereiopod. **H**, same, chela. **I**, minor second pereiopod. **J**, same, chela. **K**, third pereiopod. **L**, same, propod and dactyl. **M**, telson. **N**, uropod.

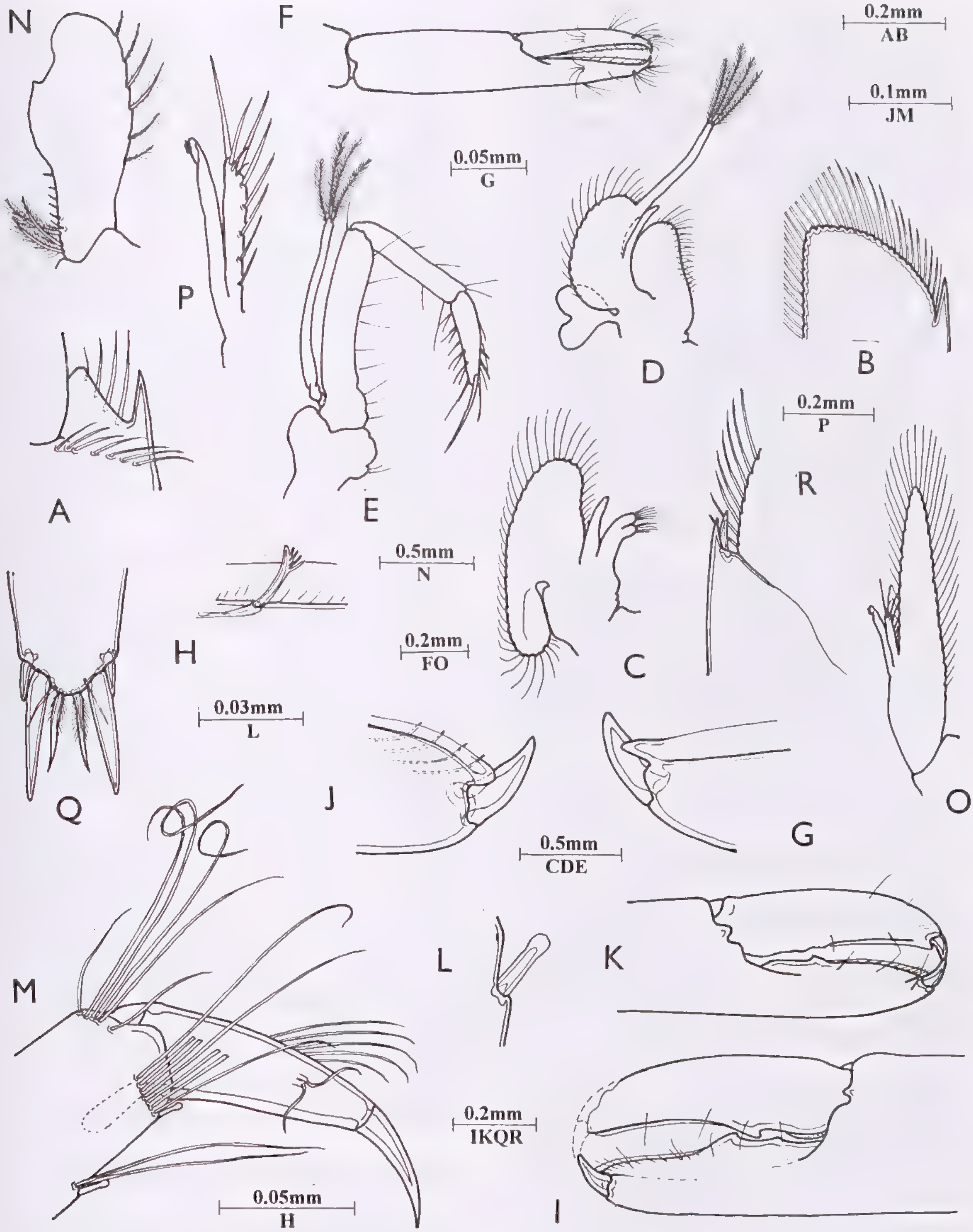

Fig. 4. *Periclimenes canalinsulae* sp. nov., holotype male, Channel Island, Darwin Harbour. **A**, antennal peduncle, proximal segment, distolateral angle. **B**, scaphocerite, distal lamella. **C**, maxilla. **D**, first maxilliped. **E**, third maxilliped. **F**, first pereiopod, chela. **G**, same, tip of fixed finger. **H**, same, seta from cutting edge. **I**, major second pereiopod chela, fingers, medial. **J**, same, tip of fixed finger, lateral. **K**, minor second pereiopod, fingers, medial. **L**, third pereiopod, propod, distoventral spine. **M**, same, distal propod and dactyl. **N**, first pleopod, endopod. **O**, second pleopod, endopod. **P**, same, appendices interna and masculina. **Q**, telson, posterior spines. **R**, uropod, exopod, posterolateral angle.

similar, with two small acute teeth proximally, distal tooth larger, more acute than proximal, distal to level of dactylar tooth, cutting edge distally sharp, entire, with distinct tooth distally, tip with stout distinctly articulated ungual spine (Fig. 4j); carpus about 0.5 of palm length, 3.0 times longer than distal width, tapering proximally, unarmed; merus subequal to palm length, unarmed, 7.5 times longer than central width, subuniform: ischium about 0.8 of merus length, 6.5 times longer than central width; basis and coxa without special features. Minor chela (Fig. 3j) about 0.55 of carapace length, 0.7 of the major chela length; palm about 4.7 times longer than distal width, tapering gradually proximally, fingers (Fig. 4k) about 0.4 of palm length, similar to major chela, dactyl with proximal cutting edge damaged, tip with strong, distinctly articulated unguis; carpus about 0.45 of palm length; proximal segments similar to major chela.

Ambulatory pereiopods slender; third pereiopod (Fig. 3k) with dactyl slender, about 2.2 of propod length (Fig. 4m), simple, corpus about 2.7 times longer than proximal depth, compressed, tapering distally, dorsal margin convex, ventral margin straight, sharp, unguis distinctly demarcated, strong, curved, about 0.5 of corpus length, deflexed, at about 135° to long axis of corpus; propod (Fig. 3l) about 0.6 of carapace length, 9.0 times longer than central depth, uniform, sparsely setose, distally with single small, short, terminally swollen distoventral spine (Fig. 4l), with single similar spine on distal ventral border, transverse rows of long simple setae ventromedially and ventrolaterally, carpus 0.6 of propod length, unarmed; merus 1.15 times propod length, unarmed; ischium 0.8 of propod length, unarmed, basis and coxa normal. Fourth and fifth pereiopods similar to third.

First pleopod with endopod 2.5 times longer than wide (Fig. 4n), cental third of medial margin expanded, with small acute process distally, distolateral border with six short sparsely setulose setae, medial margin with three plumose setae proximally, six short simple spinules along proximal third. Second pleopod endopod (Fig. 4o) with appendices (Fig. 4p) at 0.4 of medial margin length; appendix masculina with corpus slender, about 0.2 of ramus length, with eight simple spines along lateral margin, of increasing length distally, terminal spine about 2.7 of corpus length, with three small distodorsal spinules; appendix interna exceeding appendix masculina, with few distal cincinnuli.

Uropod (Fig. 3n) with protopod with small blunt distolateral lobe; exopod about 3.0 times longer than wide, lateral margin with slender acute distoventral tooth, with longer mobile spine medially, dieresis well marked; endopod subequal to exopod length, about 4.0 times longer than wide.

Measurements (mm). Carapace length, 2.6; carapace and rostrum, 4.5; total body length (approx.), 15.5; second pereiopod, major chela, 2.2; minor chela, 1.8.

Colouration. Mainly transparent, with scattered small red chromatophores along rostrum, over antennal region and distal scaphocerite, coxae of pereiopods and on second pereiopod chelae.

Etymology. From *canalis,* Latin, channel, and *insula*, Latin, an island, referring to the type locality.

Systematic position. *Periclimenes canalinsulae* is most closely related to *Periclimenes affinis* (Zehntner), a crinoid - associated species. *Periclimenes canalinsulae* may be distinguished from *P. affinis* by the following features: (i) shorter rostrum, not reaching to proximal end of distal segment of antennular peduncle, with only five dorsal teeth and without ventral tooth, first dorsal tooth situated on carapace distinctly posterior to level of posterior orbital margin, (ii) hepatic spine at same horizontal level as antennal spine, (iii) second pereiopods with chelae not markedly unequal and dissimilar, fingers with stout, conspicuously articulated tips, distal cutting edge forming blunt tooth, separated from tip by distinct notch, dactyl with single recurved acute tooth only, (iv) ambulatory propods without conspicuous transverse rows of long setae obscuring spines, spines short and blunt.

Periclimenes darwiniensis Bruce, 1987

Periclimenes darwiniensis Bruce, 1987a: 29-38, figs 1-5.

Previously recorded from East Point and Darwin Harbour (Bruce 1987a, 1988), there have been no subsequent reports of this species, which is still known only from the Northern Territory. Specimens have been collected from Bullocky Point, Fannie Bay, Dudley Point, East Point, Lee Point, Weed Reef, Channel Island, North and South Shell Islands. Also known from Barracouta Reef, Gove. Usually found in shallow intertidal pools.

Distribution. Type locality: Weed Reef, Darwin Harbour, 12°31.6'S, 130°47.3'E. Not known outside the Northern Territory.

Periclimenes diversipes Kemp, 1922

Periclimenes (Ancyclocaris) diversipes (partim) Kemp, 1922: 179-184, figs 36-39.

Periclimenes diversipes – Bruce 1971: 9-10.

Previously reported from Darwin Harbour (Bruce 1987a), specimens have also been collected from Channel Island and Lee Point. Also known from Port Essington, Northern Territory, Heron Island, Queensland and Restoration Rock, Coral Sea.

Distribution. Type locality: Kilakarai, Gulf of Manaar. Also known from Egypt, Aden, Kenya, Zanzibar, Tanganyika, Comoro Islands, Madagascar, Seychelle Islands, La Réunion, Singapore, Thailand, the Great Barrier Reef and the Coral Sea reefs.

Periclimenes elegans (Paulson, 1875)

Anchistia elegans Paulson, 1875: 113, pl. 17 fig. 1.

Periclimenes (Falciger) elegans – Borradaile 1917: 371.

Previously recorded from East Point (Bruce 1988), specimens have also been collected from Channel Island. Also known from Hibernia Reef, Timor Sea; the Cobourg Peninsula, Northern Territory, the Capricorn Islands and Swain Reefs, Queensland.

Distribution. Type locality: Red Sea. Also known from Egypt, Saudi Arabia, Kuwait, Aden, Kenya, Zanzibar, Tanganyika, Madagascar, Seychelle Islands, Minikoi, Pakistan (?), India, Sri Lanka, Andaman Islands, Nicobar Islands, Singapore, Indonesia, Hong Kong, Ryukyu Islands, the Philippines, Solomon Islands, Caroline Islands and Marshall Islands.

Periclimenes grandis (Stimpson, 1860)

Anchistia grandis Stimpson, 1860: 39.

Periclimenes grandis – Borradaile 1898: 382.

Previously reported from East Point (Bruce 1988), numerous specimens have also been collected from Bullocky Point, Cameron Beach, Channel Island, Nightcliff, Dudley Point, Shell Island, Lee Point and Weed Reef. Also known from the Cobourg Peninsula and Port Essington, Northern Territory; Port Molle and Magnetic Island, Queensland; and from North West Shelf, Western Australia.

Distribution. Type locality: Oshima, Japan. Also known from Israel, Egypt, Jibuti, Aden, Kenya, Zanzibar, Tanganyika, Moçambique, Comoro Islands, Madagascar, Seychelle Islands, Sri Lanka, Burma, Malaya, Singapore, Indonesia, Japan, Marshall Islands, Fijian Islands and Tuvalu.

Periclimenes holthuisi Bruce, 1969

Periclimenes holthuisi Bruce, 1969a: 258-259.

Previously recorded from East Point (Bruce 1988), this species is now also known from South Shell Island. Also recorded from Sandy Island No.2 and Port Essington, Northern Territory, and from Bowen, Peloris Island, Heron Island, Moreton Bay, Queensland. Also known from Lord Howe Island. Associated with Actinaria, Scleractinia and Scyphozoa

Distribution. Type locality: Lung Ha Wan, Hong Kong. Recorded from the Red Sea, Zanzibar, Maldive Islands, Sri Lanka, Malaya, Singapore, Indonesia, Vietnam, South China Sea, Japan, the Philippines, Papua-New Guinea, New Caledonia, Caroline Islands and Marshall Islands.

Periclimenes incertus Borradaile, 1915

Periclimenes (Cristiger) incertus Borradaile, 1915: 210.

Periclimenes incertus – Bruce 1969a: 276-277: 1971: 8.

Previously reported from East Point (Bruce 1988), further specimens have been collected from Channel Rock, Weed Reef and South Shell Island. Also known from Northwest Cape, Western Australia, Port Essington, Sandy Island No.2, Northern Territory, Heron Island and Moreton Bay, Queensland.

Distribution. Type locality: South Nilandu Atoll, Maldive Islands. Also known from Aden, Kenya, Zanzibar, Tanganyika, Madagascar, Sri Lanka, Andaman Islands, Singapore, Indonesia, Philippines, and New Caledonia.

Periclimenes indicus (Kemp, 1915)

Urocaris indica Kemp, 1915: 275-279, fig. 26, pl. 13 fig. 9.

Periclimenes (Periclimenes) indicus – Kemp 1922: 144, fig. 13.

Not previously recorded from Darwin Harbour, specimens have been collected from

Bullocky Point and Dudley Point, from intertidal pools. Also known from Trepang Bay and Port Essington, Northern Territory and Moreton Bay, Queensland.

Distribution. Type locality: Chilka Lake, Orissa; the Adyar River and Ennur Backwater, Madras, India. Also known from the Nicobar Islands, Malaya, Singapore and Indonesia.

Periclimenes investigatoris Kemp, 1922
(Fig. 5)

Periclimenes (Periclimenes) investigatoris Kemp, 1922: 160-1162, figs 26-27, pl. V, fig. 6.

Not previously recorded from the Northern Territory, a single example that is provisionally referred to this species has been collected from 3.5 m at Woods Inlet (12°31.0'S, 130°44.0'E, 30 August 1985, NTM Cr.003313). The ovigerous female specimen is in poor condition, macerated, and with only a single damaged (minor) second pereiopod. The specimen (Fig. 5a) has a carapace length of 2.6mm and a rostral dentition of 9/2, with a moderately deep lamina, reaching to about the end of the antennular peduncle, and with two teeth situated on the carapace. The holotype has only a single tooth on the carapace and a single ventral rostral tooth (Kemp 1922). The stylocerite (Fig. 5b) is long and slender, but not as long as in the holotype, and does not reach the level of the base of the intermediate segment of the antennular peduncle. As far as can be determined, the remaining second pereiopod is compatible with Kemp's description. The detached fourth pereiopod has a dactyl (Fig. 5d) closely resembling that of the third pereiopod as illustrated by Kemp (1922, Fig. 27b). Kemp mentions only the presence of setae on the ventral propod, but his figure shows a well developed distoventral spine. The propodal spines (Fig. 5c) in the present specimen are largely broken but seem to have been long. The thoracic sternites are narrow and the fourth is unarmed. Also reported from an unspecified Queensland

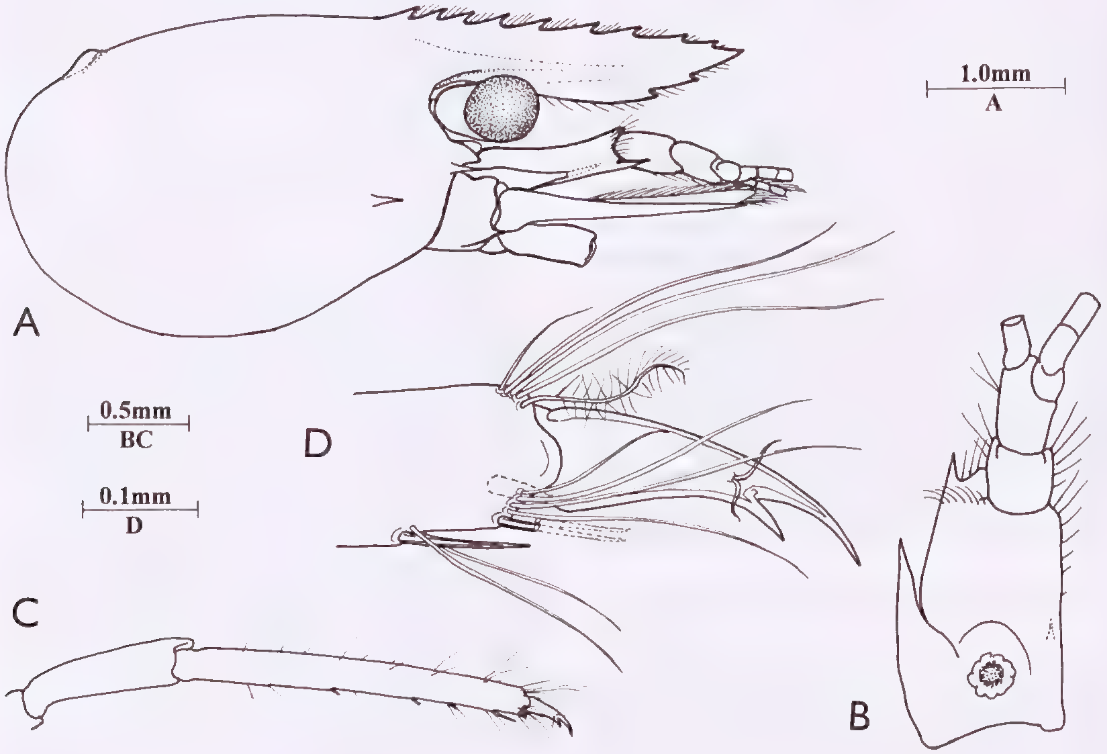

Fig. 5. *Periclimenes investigatoris* Kemp, ovigerous female, Woods Inlet, Darwin Harbour, NTM Cr.003313. **A**, carapace, eye and antennal peduncles. **B**, antennular peduncle. **C**, fourth pereiopod, carpus, propod and dactyl. **D**, same, distal propod and dactyl.

east coast locality. A Malayan specimen was reported from 6m, in association with a nephthyid alcyonacean (Johnson 1976).

Distribution. Type locality: Persian Gulf, 29°20'N, 48°47'E, 24m. Also reported from Malaya and Singapore.

Periclimenes kempi Bruce, 1969

Periclimenes kempi Bruce, 1969a: 260-261.

Previously recorded from East Point (Bruce 1988), further material has been collected from Buffalo Creek. Also known from Cartier Reef, Timor Sea, Port Essington, Northern Territory, and from Heron Island, Queensland. Associated with Alcyonacea.

Distribution. Type locality: Port Blair, Andaman Islands. Also known from Egypt, Kenya, Zanzibar, Singapore and Fijian Islands.

Periclimenes novaffinis sp. nov.
(Fig. 6)

Material examined. HOLOTYPE, 1 ovig.♀, off East Point, Darwin Harbour, 12°25.92'S, 130°48.72E, 8 m, coll. L. Vail, NTM Cr.004484, PARATYPES 1 ♂, Fannie Bay, Darwin Harbour, 12°29.92'S, 130°48.68'E, 10 m, 23 September 1986, coll. L. Vail, NTM Cr.004216. 1 juv. ♂, 1 ♀, Bullocky Point, Darwin Harbour, 12°26.08'S, 130°49.98'E, 6 m, 25 November 1986, coll. L. Vail, NTM Cr.004473.

Description. A small sized, slender *Periclimenes* species, of subcylindrical body form, generally similar to *P. affinis*.

Rostrum (Fig. 6a) slender, straight, horizontal, about 0.85 of carapace length, reaching to middle of distal segment of antennular peduncle, with eight acute evenly spaced dorsal teeth, first tooth situated posterior to orbital margin, lateral carinae obsolete, ventral carina obsolete, margin feebly convex, with single small distal tooth, with short plumose median setae proximally. The Fannie Bay male specimen without ventral tooth. Carapace (Fig. 6a) smooth, glabrous, epigastric and supraorbital spines absent, orbit feebly developed, inferior orbital angle strongly produced, acute in lateral view, antennal spine well developed, marginal, subequal to inferior orbital angle, hepatic spine subequal to antennal spine, inferior to level of antennal spine, anterior to level of first dorsal rostral tooth, anterolateral angle of branchiostegite broadly rounded, not produced.

Abdomen as in *P. affinis*, smooth, glabrous, third tergite not posterodorsally produced, pleura broadly rounded, sixth segment about 1.75 times length of fifth, 1.6 times longer than anterior depth, 0.7 of carapace length, posteroventral angle bluntly produced, posterolateral angle acutely produced. Telson (Fig. 6m) about 1.1 times sixth segment length, 3.5 times longer than anterior width, lateral margins straight, convergent, with two pairs of small marginal, dorsal spines, at 0.5, 0.8 of length, posterior margin (Fig. 6n) about 0.33 of anterior width, angular, centrally produced, without median point, lateral spines subequal to dorsal spines, subdorsal, intermediate spines stout, blunt, about 0.2 of telson length, submedian spines slender, setulose, about 0.45 of intermediate spine length.

Antennular peduncle normal, as in *P. affinis*, proximal segment about 2.3 times longer than central width, with acute ventromedial tooth, distolateral angle bluntly produced, with strong acute lateral tooth, extending well beyond distal margin of lobe, statocyst with lobulate statolith, stylocerite slender, acute, reaching to about 0.5 of segment length, intermediate and distal segments normal, combined lengths about 0.75 of proximal segment length, upper flagellum with proximal four segments of rami fused, shorter free ramus with four segments, with 11 groups of aesthetascs, longer ramus and lower flagellum slender, filiform.

Antenna (Fig. 6a) as in *P. affinis*, with basicerite with well developed lateral tooth, carpocerite not exceeding proximal segment of antennular peduncle, about 2.5 times longer than central width, reaching to about 0.5 of scaphocerite length, flagellum well developed; scaphocerite about 3.5 times longer than central width, lateral margin straight with strong distolateral tooth, lamella broad, scarcely tapering, distally bluntly angular, far exceeding distolateral tooth (Fig. 6a).

Eye (Fig. 6b) with large globular cornea, diameter about 0.2 of carapace length, with dorsal accessory pigment spot, stalk about 1.2 times longer than wide, 1.2 times longer than corneal diameter.

Mouthparts not examined in detail, of normal *Periclimenes* form. Fourth thoracic sternite without median process, fourth and fifth sternites without transverse ridges.

First pereiopods slender (Fig. 6c), merus reaching to distal end of carpocerite, chela (Fig. 6d) with palm subcylindrical, about 2.0 times longer than deep, fingers slender, compressed, about 0.8 of palm length, tips acute, strongly hooked, cutting edges well developed, entire, laterally situated; carpus (Fig. 6c) about 0.8 of chela length, subcylindrical, about 4.0 times longer than distal width; merus distinctly longer than carpus, about 1.1 times chela length, uniform, 6.0 times longer than central width; ischium about 0.6 of merus length; basis normal; coxa with well developed setose ventral lobe.

Second pereiopods generally similar, unequal (Fig. 6e-i); major chela (Fig. 6e) about 1.1 of carapace length, chela (Fig. 6f) with palm subcylindrical, slightly compressed, smooth, about 4.0 times longer than distal width, slightly swollen proximally, fingers (Fig. 6g) robust, about 0.45 of palm length, dactyl with tip damaged, about 4.0 times longer than deep, cutting edge with single small acute, recurved tooth at about 0.33 of length, distal cutting edge lateral, entire, sharp, fixed finger similar, with two larger, acute teeth proximally, distal tooth larger, more acute than proximal, distal to level of dactylar tooth, cutting edge distally sharp, entire, tip strongly hooked; carpus about 0.45 of palm length, 3.5 times longer than distal width, tapering proximally, unarmed; merus longer than carpus, equal to 0.66 of palm length, half chela length, unarmed, 6.0 times longer than central width, subuniform: ischium about 1.2 times merus length, 7.5 times longer than central width; basis and coxa without special features. Minor chela (Fig. 6h) about 0.65 of carapace length, 0.6 of the major chela length; palm about 3.0 times longer than distal width, subcylindical, fingers (Fig. 6i) subequal to palm length, similar to major chela, more slender, proximal cuttings edge entire, tips acute, feebly hooked, carpus subequal to palm length; more slender, proximal segments similar to major chela.

Ambulatory pereiopods slender; third pereiopod with dactyl (Fig. 6l) slender, about 0.2 of propod length, simple, corpus about 2.0 times longer than proximal depth, compressed, tapering distally, dorsal margin convex, ventral margin sublinear, sharp, unguis indistinctly demarcated, strong, curved, about 0.5 of corpus length, deflexed; propod (Fig. 6j) about 0.6 of carapace length, 10.5 times longer than central depth, uniform, sparsely setose, distal half of ventral border with four well developed slender spines, with similar pair of distoventral spines (Fig. 6k), carpus 0.6 of propod length, unarmed; merus 1.15 times propod length, unarmed; ischium 0.6 of propod length, unarmed, basis and coxa normal. Fourth and fifth pereiopods similar to third.

First pleopod with endopod 3.5 times longer than wide, tapering distally to acute tip, lateral margin sparsely setose, three short plumose setae only, medial margin with well developed accessory lobe, with three short stout plumose setae proximally. Second pleopod endopod with appendices at about 0.4 of medial margin length; appendix masculina with corpus slender, with two long simple distal spines, two shorter distodorsal spines; appendix interna far exceeding appendix masculina, with few distal cincinnuli. Uropod (Fig. 6o) as in *P. affinis*, with protopod with small blunt distolateral lobe; exopod about 3.5 times longer than wide, lateral margin with slender acute distoventral tooth, with large mobile spine medially, dieresis obsolete; endopod about 0.85 of exopod length, about 4.0 times longer than wide.

Measurements (mm). Ovigerous female holotype: carapace length, 2.1; carapace and rostrum, 3.75; total body length (approx.), 10.5; second pereiopod, major chela, 2.8; minor chela, 1.6; length of ovum, 0.4.

Colouration. The colour pattern exhibited in life varied with the host crinoid. On *Zygometra punctata*: anterodorsal carapace and rostrum finely dotted with small red spots, antennal peduncles similar, ventral body reddish, tips of telson and uropods white. On *Zygometra elegans*: semitransparent, with red median dorsal line on abdomen, white chromatophores along intestine and over stomach, dense median line of small red chromatophores along whole ventral body surface, cornea and tips of caudal fan white.

Hosts. All specimens were associated with crinoid hosts. The holotype was on *Zygometra andromeda*, the Bullocky Point paratype on *Zygometra punctata*, and the Fannie Bay paratype on *Zygometra elegans*.

Etymology. From *novum,* Latin, new, and *affinis*, the specific name for a species of *Periclimenes* originally described by Zehntner (1894).

Systematic position. Closely related to *Periclimenes affinis* (Zehntner), the holotype of which was redescribed by Holthuis (1958). *Periclimenes novaffinis* differs from *P. affinis* in the following features: (i), the rostrum distinctly shorter than antennular peduncle, reaching only to middle of terminal segment, with small, near terminal ventral tooth, instead of a larger tooth at about 0.6 of the ventral marginal length: (ii), the very short carpus on the first pereiopod,

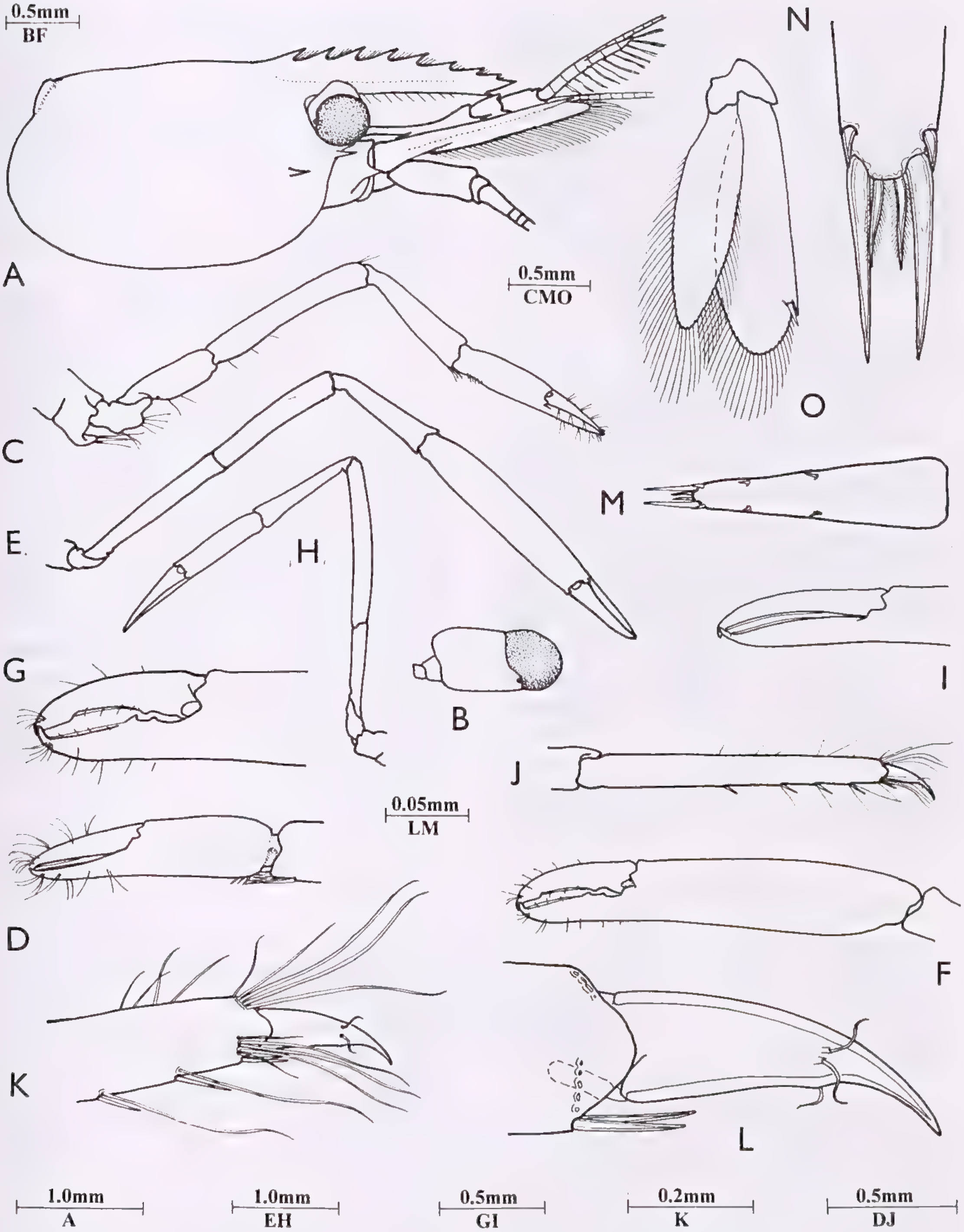

Fig. 6. *Periclimenes novaffinis* sp. nov., ovigerous female holotype, off East Point, Darwin Harbour. **A**, carapace and rostrum, eye, and antennal peduncles. **B**, eye, dorsal. **C**, first pereiopod. **D**, same, chela. **E**, major second pereiopod. **F**, same, chela. **G**, same, fingers. **H**, minor second pereiopod. **I**, same, fingers of chela. **J**, third pereiopod, propod and dactyl. **K**, same, distal propod and dactyl. **L**, same, dactyl. **M**, telson. **N**, same, posterior spines. **O**, uropod.

which is distinctly less than the length of the chela, in contrast to about 1.5 times the chela length in *P. affinis*: (iii), the carpus of the major second pereiopod about 0.5 of the palm length, rather than distinctly less than half the palm length, about 0.3 times in *P. affinis*: (iv), ambulatory pereiopods with conspicuous ventral and distoventral spines and sparsely setose, in contrast to feebly spinose, with dense rows of distal setae and (v), ambulatory dactyls with comparatively robust unguis, about 0.5 of the corpus length, in contrast to a very slender unguis, equal to about 0.6 of the corpus length in *P. affinis*.

Although Holthuis (1958) reported in his redescription of *P. affinis* that the ambulatory propods were devoid of ventral spines, it was subsequently confirmed by B. Hauser, that spines, largely concealed by setae, were present (Bruce 1980). Holthuis also noted that "the distal half of the dactylus is very narrow and is sharply set off from the basal half which is broader", which is markedly different from the present species.

Periclimenes novaffinis also appears closely related to *P. jugalis* Holthuis, still known only from the holotype specimen from Djedan Island, Aru Islands, Indonesia, collected in 1899, and a specimen reported from Zanzibar Harbour by Bruce (1976). In this species the carpus of the second pereiopod is longer than the chela, the carpus of the major second pereiopod is about half the chela length rather than about 0.5 of the palm length, and the rostrum is more slender, slightly decurved, with nine dorsal teeth and two distal ventral teeth. The ambulatory propod and dactyl appear similar in the two species, with conspicuous ventral spines on the propods. The host of *P. jugalis* has not been established. *Periclimenes novaffinis* is also similar to *P. canalinsulae* (as described above) and may be distinguished by the differences in rostrum, rostral dentition and the very short carpus of the first pereiopod.

Periclimenes obscurus Kemp, 1922

Periclimenes (Periclimenes) obscurus Kemp, 1922:144-146, figs 14-15.

Periclimenes obscurus – Bruce 1969a: 272-273, 275-277.

Previously recorded from 10 m at East Point (Bruce 1988), further specimens have been collected from Fannie Bay and Woods Inlet. Also known from Orontes Reef and Port Essington, Northern Territory and Moreton Bay, Queensland.

Distribution. Type locality: Ennur Backwater, Madras Harbour, India. Also known from Kuwait, Kenya, Zanzibar, Tanganyika, Madagascar and New Caledonia.

Periclimenes suvadivensis Borradaile, 1915

Periclimenes (Periclimenes) suvadivensis Borradaile, 1915: 212.

Periclimenes suvadivensis Bruce, 1978: 264-266, fig. 8.

Not previously recorded from Australia, specimens provisionally referred to this species are under study by Karen Coombes. They have been found to be common in the Channel Island area of Darwin Harbour, in muddy pools. The species is known only from the type material, the habitat of which was unfortunately not recorded.

Distribution. Type locality: Suvadiva Atoll, Maldive Islands. No further records.

Periclimenes tenuipes Borradaile, 1898

Periclimenes tenuipes Borradaile, 1898: 384.

Previously recorded from Anglers Reef (Bruce 1983b) and East Point (Bruce 1988), further specimens are now known from Bullocky Point, Channel Island and South Shell Island. Also known from Hibernia Reef, Timor Sea, and from Trepang Bay and Port Essington, Northern Territory. Also known from Heron Island, Queensland. Common in intertidal pools and apparently free-living, although also reported to be an anemone associate elsewhere.

Distribution. Type locality: Ralun, New Britain. Also known from Jordan, Kenya, Zanzibar, Madagascar, La Réunion, Seychelle Islands, Maldive Islands, Sri Lanka, Andaman Islands, Indonesia, the Philippines, New Caledonia, Caroline Islands and Marshall Islands.

Periclimenes toloensis Bruce, 1969

Periclimenes toloensis Bruce, 1969a: 273-275.

Previously recorded from East Point (Bruce 1988), further specimens have been collected from off East Point, and from Elliot Point, North Shell Island, and from Fort Hill Wharf. Also known from Trepang Bay, Port Essington, Orontes Reef, Sandy Island No.2, Oxley Island and McCluer Island, Northern Territory, and from Wistari Reef, Queensland. An associate of hydroid coelenterates, particularly *Lytocarpus* and *Aglaophenia*.

Distribution. Type locality: Ap Chau, Tolo Channel, Hong Kong. Also known only from Zanzibar and the Philippines.

Periclimenes sp.
(Fig. 7)

Two male specimens of this taxon have been collected from the mouth of Ludmilla Creek (stn HL82-2, coll. H.K. Larson, 11 January

1982, NTM Cr.000144), from a muddy mangrove creek. Belonging to the *P. grandis* group, *sensu* Kemp, they can not be satisfactorily referred to any of the described species of that group. They were initially identified as *P. suvadivensis* Borradaile or possibly *P. andamanensis* Kemp, but appear to differ from both those species. The *P. grandis* group represent a complex of closely related species the relationships of which are not always very clear and the description of a further species may create more problems than it resolves, pending a proper revision of the group, which is clearly necessary.

The larger specimen (CL 1.7 mm), has a rostral dentition of 6/0 in addition to an epigastric spine, with the rostrum extending well beyond the tip of the scaphocerite (Fig. 7a), about 1.45 times the carapace length. In the type material of *P. suvadivensis* the rostrum has a dentition of 5/2 in addition to the epigastric spine and is about 1.15 times the carapace length only (Bruce 1978). The smaller specimen has both second pereiopods, which are subequal and similar. The larger specimen has only a single second pereiopod (Fig. 7b). The chela is about 1.2 times the carapace length. In *P. suvadivensis* the chela is about 2.5 times the carapace length. The carpus is elongate, subequal to the chela length, and distinctly longer than the merus, whereas in *P. suvadivensis* the carpus is about 0.6 of the chela length. The fingers are slender and feebly dentate, subequal to the palm length (Fig. 7c). In *P. suvadivensis* the fingers are much shorter, about 0.5 of the palm length. The palms of these male chelae are smooth and lack the minute asperities found in males of other species of this species group. The carpo- propodal articulation (Fig. 7d) is feebly armed. In *P. andamanensis* the carpus of the male second pereiopod is shorter than the merus, and the fingers are also about 0.5 of the palm length, as in *P. suvadivensis*.

The specimens also show a close resemblance to the specimens from Nouméa referred to *P. agag* by Ledoyer (1984). The New Caledonian specimens have the carpus of the second pereiopod distinctly exceeding the length of the palm of the chela, but not nearly equalling the chela length; the fingers of the chela are also distinctly shorter than the palm length, in the males. In the female, the carpus does almost equal the chela length, but the fingers are still much shorter than the palm length.

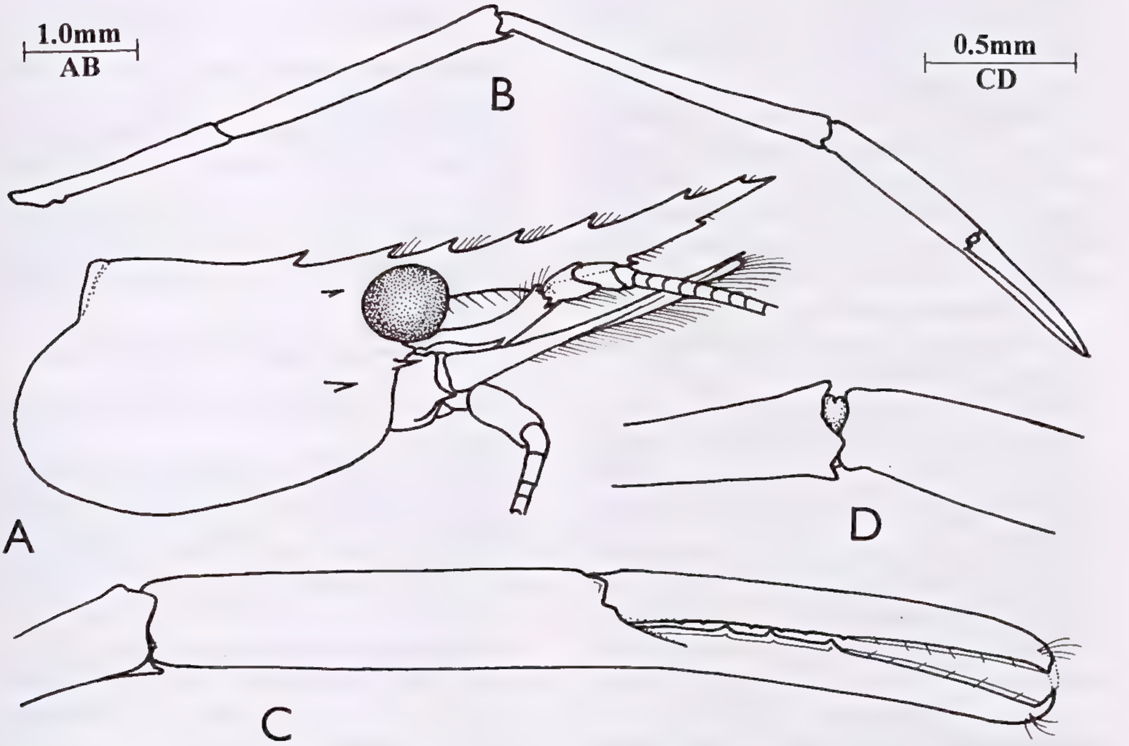

Fig. 7. *Periclimenes* sp., male, Ludmilla Creek, Darwin Harbour. **A**, carapace, rostrum, eye and antennal peduncles. **B**, second pereiopod. **C**, same, chela. **D**, same, carpo-propodal joint, dorsal.

Typtonychus anomalus (Bruce, 1979)

Onycocaris anomala Bruce, 1979: 69-78, figs 1-4.

Typtonychus anomalus – Bruce 1996: 253.

Collected in 1929, these specimens were not described till half a century later, and the species is still known only from the type specimens, now in the Australian Museum. The two ovigerous female specimens were obtained by dredge from 6-14m and were most probably from a sponge host.

Distribution. Type locality: between North and South Shell Islands. No further records.

ANCHISTIOIDIDAE Borradaile, 1915

Anchistioides willeyi (Borradaile, 1899)

Palaemonopsis willeyi Borradaile, 1899: 410, pls 36,37, fig. 7.

Anchistioides willeyi – Gordon 1935: 435, figs 23a, 24a.

Previously reported from Darwin Harbour, with a single specimen from a sponge host from 10 m off East Point (Bruce 1988), no further specimens have been collected. Also known from the Cobourg Peninsula, Northern Territory. Two "forms" of this species have been reported, "long-fingered" and "short-fingered", with reference to the second pereiopod chelae: the Darwin Harbour specimen belongs to the long fingered form.

Distribution. Type locality: Ralun, New Britain. Also known from Kenya, Zanzibar, Tanganyika, Madagascar, Maldive Islands, Indonesia, South China Sea, the Philippines and New Caledonia.

ALPHEIDAE Rafinesesque, 1815

Alpheus acutocarinatus De Man, 1909

Alpheus acutocarinatus De Man, 1909:104.

Not previously recorded from the Northern Territory. A single damaged female has recently been collected from the West Arm of the Harbour (12°37.0'S, 130°48.8'E, 4 December 1993) at a depth of 5m. The only other Australian report of this species is from Moreton Bay, Queensland. The specimen agrees well with earlier descriptions but appears to lack the usual small tooth on the post-rostral carina, but the carapace is soft and rather damaged.

Distribution. Type locality: four localities in Indonesia. Also known only from Madagascar, Thailand, Vietnam and the Philippines.

Alpheus acutofemoratus Dana, 1852

Alpheus acutofemoratus Dana, 1852b: 550, pl. 35, fig. 2.

Previously recorded from East Point, (Bruce 1988). No further specimens have been collected from the Harbour region. Also known from Torres Strait, Green Island and Heron Island, Queensland.

Distribution. Type locality: Balabac Strait, the Philippines/Indonesia. Also known from the Andaman Islands, Indonesia, Thailand, Fijian Islands, Cook Islands, Marshall Islands and Samoan Islands.

Alpheus balaenodigitus Banner and Banner, 1982

Alpheus balaenodigitus Banner and Banner 1982: 223-225, fig. 70.

Reported from Darwin by Banner and Banner (1982), a further specimen has since also been collected from Channel Island. Known only from the Northern Territory and Western Australia.

Distribution. Type locality: Port Walcott, Western Australia. Not known from outside Australian waters.

Alpheus bannerorum Bruce, 1987

Alpheus bannerorum Bruce, 1987b: 61-72, figs 1-6, pl. 1.

First described from specimens from East Point and Channel Island. Now also known from Nightcliff Beach. Specimens have also been recorded from Heron Island, Queensland.

Distribution. Type locality: East Point, Darwin Harbour. Known also only from Hong Kong.

Alpheus bisincisus De Haan, 1844

Alpheus bisincisus De Haan, 1844: pl. 45 fig. 3; 1849: 179.

A single specimen was reported from East Point by Bruce (1988) and no further specimens have since been collected from the Harbour region. Also reported from northwest Australia, the Gulf of Carpentaria, and southern Queensland.

Distribution. Type locality: Japan. Also known from South Africa, Maldive Islands, Laccadive Islands, Sri Lanka, Indonesia, Singapore and Japan.

Alpheus brevicristatus De Haan, 1844

Alpheus brevicristatus De Haan, 1844: pl. 45 fig. 1; 1849: 177.

Specimens of this species from Darwin Harbour are presently under study by Dr Y. Miya. Not previously reported from the Northern Territory.

Alpheus chiragricus Milne-Edwards, 1837

Alpheus chiragricus Milne-Edwards, 1837: 354.

First reported by Banner and Banner (1982) from Darwin. A single example was reported from East Point (Bruce 1988), and further specimens have also been collected from Fannie Bay, Woods Inlet, Shell Island and Channel Island. Also known from Cape Jaubert, Cockburn Sound, Port Hedland, and Broome, Western Australia, the Gulf of Carpentaria and Queensland south to Port Curtis.

Distribution. Type locality: "Mers d'Asie". Also known from East Africa, Madagascar, Indonesia and Burma.

Alpheus cristatus Coutière, 1897

Alpheus cristatus Coutière, 1897: 303.

Originally described from Thursday Island and first recorded from Darwin by Banner and Banner (1982). Previously reported as common in Darwin Harbour (Bruce 1988). Known from East Point, Dudley Point, Fannie Bay, Weed Reef, Channel Island, and North and South Shell Islands. Also from Cape Leveque, Western Australia.

Distribution. Type locality: Thursday Island, Queensland. Otherwise reported only from the Maldive Islands.

Alpheus diadema Dana, 1852

Alpheus diadema Dana, 1852b: 555, pl. 35, fig. 7.

Previously reported from East Point (Bruce 1988), no further specimens have been collected. Also known from the Low Isles and reported from the Australian east coast from Port Douglas to the Whitsunday Islands and the Coral Sea. Possibly also from Beagle Bay, Western Australia.

Distribution. Type locality: Lahaina, Maui, Hawaii. Extensively distributed from the Red Sea and East Africa, Indian Ocean to Japan, Indonesia, the Philippines, and tropical Pacific to Hawaii.

Alpheus digitalis De Haan, 1844

Alpheus digitalis De Haan, 1844: pl. 45, fig. 4; 1849: 178.

Alpheus distinguendus De Man, 1909: 155, pl. 7, figs 9-14.

Specimens from Darwin Harbour are presently under study by Dr Y. Miya. Not previously recorded from the Northern Territory.

Alpheus edwardsii (Audouin, 1827)

Alpheus Edwardsii Audouin, 1827: 274.

Alpheus edwardsii Banner and Banner 1973b: 1142, 1 fig.

First reported from Darwin by Miers (1874), in his report upon material collected by the HMS *Erebus* and *Terror* Expedition, with other specimens from Port Essington. The specimen is still held in the collection of the Natural History Museum, dry, registration number 1845.51 and was presented by the Earl of Derby, probably having been collected by MacGillivray during the voyage of HMS *Fly* (Paul Clark pers. comm. 21 Feb. 1994). Pope (1949) also reported this species from Darwin. Also known from Cape Jaubert and Monte Bello Islands, Western Australia, Thursday Island, and Low Islands, Queensland, Middleton Reef and Norfolk Island, Coral Sea, and Kangaroo and Dirk Hartog Islands, South Australia. Banner and Banner (1982) note that specimens have been examined from all coasts of Australia.

Distribution. Type locality: Suez, Egypt (neotype). Also known with certainty only from the Red Sea, Thailand, and the Philippines, probably extending widely through the Indian Ocean and Southeast Asia (Banner and Banner 1982).

Alpheus euphrosyne De Man, 1897

Alpheus euphrosyne De Man, 1897: 745, fig. 64 a-d.

Not previously reported from Darwin Harbour. Specimens have been collected in mangroves from Ludmilla Creek, Channel Island, and the mouth of the Blackmore River. Also known from Townsville to Princess Charlotte Bay, Queensland. Probably widespread along all tropical coasts (Banner and Banner 1982).

Distribution. Type locality: Java Sea. Also known from Kenya, Thailand, Indonesia and the Philippines.

Alpheus facetus De Man, 1908

Alpheus facetus De Man, 1908: 100.

Previously reported from East Point (Bruce 1988). Specimens have been collected from East Point, Dudley Point, Gunn Point, Ludmilla Creek, and Channel Island. Also known from near Perth to Yampi Sound, Western Australia, Darwin, Northern Territory, Gulf of Carpentaria, Thursday Island, and from Port Douglas, Queensland, to near Sydney, New South Wales (Banner and Banner 1982).

Distribution. Type locality: off Djedan, Kepulauan Aru, Indonesia. Also known from Somalia, Madagascar, Mauritius, Thailand, Vietnam and the Philippines.

Alpheus gracilipes Stimpson, 1860

Alpheus gracilipes Stimpson, 1860: 31.

Previously reported from East Point (Bruce 1988) and now also known from Nightcliff Beach. Also known from Thursday Island, Murray Island, Low Island, Queensland. Also recorded from Yampi Sound and Cape Leveque, Western Australia, and from the Coral Sea south to Heron Island, Queensland (Banner and Banner 1982).

Distribution. Type locality: Tahiti, Society Islands. Also known from the Red Sea, Somalia, Kenya, Tanzania, Madagascar, Comoro Islands, Seychelle Islands, La Réunion, Indonesia, Vietnam, Korea, Hong Kong, Ryukyu Islands, New Caledonia, and across the central Pacific to Hawaii and Tahiti (Banner and Banner 1982; Chace 1988).

Alpheus heronicus Banner and Banner, 1982

Alpheus heronicus Banner and Banner, 1982: 220-223, fig. 69.

Previously recorded from East Point (Bruce 1988), no further specimens have been obtained. Also known from Heron Island, and Moreton Bay, Queensland.

Distribution. Type locality: Heron Island, Capricorn Islands, Queensland. Not known outside Australian waters.

Alpheus leviusculus Dana, 1852

Alpheus Edwardsii var. *leviusculus* Dana, 1852b: 543.

Alpheus leviusculus — Dana 1855, pl. 34, fig. 3a-f.

Not previously recorded from Darwin Harbour, a specimen has been collected from about 5 m at Fort Hill Wharf, from a sponge on a raised pontoon. Not known elsewhere in the Northern Territory. Reported by Banner and Banner (1982) from Diamond Islet, south to Heron Island, Queensland.

Distribution. Type locality: Wake Island, North Pacific. Also known from the Red Sea, eastern Africa, Indian Ocean, Indonesia and Pacific Islands east to Wake Island (Chace 1988).

Alpheus lobidens De Haan, 1849

Alpheus lobidens De Haan, 1849: 179.

Alpheus inopinatus Holthuis and Gottlieb, 1958: 42, figs 8-9.

First reported from Cape York by Bate (1888). Previously reported from East Point (Bruce 1988). Also now known from Bullocky Point, Ludmilla Creek, Weed Reef, and Channel Island. Also known from Houtman Abrolhos Islands, Western Australia, Gulf of Carpentaria, Torres Strait, east coast to Sydney, New South Wales, and Lord Howe Island (Banner and Banner 1982).

Distribution. Type locality: near Nagasaki (?), Japan. Also known throughout the entire Indo-West Pacific region from the northern Red Sea to Hawaii, and also from the east and central Mediterranean Sea.

Alpheus lottini Guérin, 1829

Alpheus Lottini Guérin, 1829: pl. 3 fig. 3; 1838: 38.

Two specimens recorded from an intertidal coral from East Point (Bruce 1988), no further material has been recorded from Darwin Harbour. This record was considered to be dubious, as pocilloporid corals do not now occur in Darwin Harbour, and remains unconfirmed. However, Banner and Banner (1982) also recorded the presence of this species from Darwin Harbour. Also known from Perth to the Dampier Archipelago, Western Australia, Torres Strait, Princess Charlotte Bay, Queensland, to Sydney, New South Wales and from Lord Howe Island.

Distribution. Type locality: New Ireland, Bismarck Archipelago. Also known from the Red

Sea, East Africa, to Hawaii, Galapagos Islands, Gulf of California, to Colombia.

Alpheus maindroni Coutière, 1898

Alpheus maindroni Coutière, 1898b: 113, figs 2, 2'.

Previously reported from East Point (Bruce 1988), further material has also been collected from Nightcliff Beach. Otherwise only known in Australian waters from Green Island, Queensland, and from near Angourie, New South Wales.

Distribution. Type localities: Masqat, Oman, and Djibouti, Gulf of Aden. Also known from Moçambique, Madagascar, Indonesia, the Philippines, Caroline Islands and Marshall Islands.

Alpheus malabaricus (Fabricius, 1775)

Astacus malabaricus Fabricius, 1775: 415.

Alpheus macrodactylus Ortmann, 1890: 473, pl. 36, fig. 10. – Chace 1988: 39, fig. 9.

Alpheus malabaricus – Banner and Banner 1966: 145, fig. 55.

Specimens of this species from Darwin Harbour are presently under study by Dr Y. Miya. Not previously reported from the Northern Territory.

Alpheus microstylus (Bate, 1888)

Betaeus microstylus Bate, 1888: 566, pl. 101, fig. 6.

Alpheus microstylus – Coutière 1905: 884, fig. 23.

Bruce (1988) recorded a single ovigerous female from East Point. No further specimens have been subsequently collected. In Australian waters still otherwise only known from the type specimen from Cape York, Queensland.

Distribution. Type locality: Albany Island, Cape York. Also known from the Red Sea, Madagascar, Seychelle Islands, Maldive Islands, Laccadive Islands, Indonesia, Vietnam, the Philippines, Caroline Islands, Mariana Islands and Samoan Islands.

Alpheus pacificus Dana, 1852

Alpheus pacificus Dana, 1852b: 544, pl. 34, fig. 5.

Four specimens recorded from East Point reef pools by Bruce (1988), no further specimens have been collected from Darwin Harbour. One of the commonest Indo-West Pacific *Alpheus* species. In Australia known from Perth to Northwest Cape, Western Australia, the Gulf of Carpentaria, and from Cooktown, Queensland, to Sydney, New South Wales: also from Norfolk and Lord Howe Islands.

Distribution. Type locality: Hawaii. Widespread throughout most of the Indo-West Pacific region, from the Red Sea, East Africa, to Clipperton Island in the Eastern Pacific region.

Alpheus paracrinitus Miers, 1881

Alpheus paracrinitus Miers, 1881: 365, pl. 16, fig. 6.

Not previously recorded from Darwin Harbour, a single example has been collected from Bullocky Point. Also known only from Herald Cay and Heron Island, Queensland.

Distribution. Type locality: Gorée Island, Senegal. Pantropical, from the Red Sea to the Ryukyu Islands, to Hawaii and the Society Islands, to Clipperton Island, the Gulf of Mexico and Caribbean, and West Africa.

Alpheus pareuchirus Coutière, 1905

Alpheus pareuchirus Coutière, 1905: 906, pl. 84, fig. 43.

Previously recorded from East Point (Bruce 1988). No further specimens have been collected from Darwin Harbour. Also known from Port Hedland, Western Australia, and the Percy Islands, Queensland.

Distribution. Type locality: Malé Atoll, Maldive Islands. Also known from the Red Sea, Madagascar, Seychelle Islands, Thailand, Indonesia, the Philippines and Caroline Islands.

Alpheus parvirostris Dana, 1852

Alpheus parvirostris Dana, 1852b: 551, pl. 35 fig. 3.

First reported from Darwin by Banner and Banner (1982). Noted as moderately common in intertidal pools at East Point (Bruce 1988), specimens have also been collected from Channel Island. Also known from Houtman Abrolhos Islands to Cockatoo Island, Western Australia, Torres Strait, and Cooktown to the Capricorn Islands, Queensland.

Distribution. Type locality: Balabac Strait, Indonesia/the Philippines. Also known from the Red Sea, east and south Africa, to Indonesia, the Philippines, Japan, to the Tuamotu Islands.

Alpheus praedator De Man, 1908

Alpheus praedator De Man, 1908: 103.

Reported as common in intertidal pools at East Point by Bruce (1988), and now also known from Channel Island.

Distribution in Australia uncertain due to confusion of this species with *A. bidens* (Olivier), a primarily southern species (although a specimen has been identified from the Cobourg Peninsula). The two species appear to be consistently separable by the presence of distinct acute teeth on the dorsomedial angle of the distal margin of the proximal segment of the antennular peduncle in *A. praedator* and their absence in *A. bidens*, as well as other features.

Distribution. Type locality: Ambon, Indonesia. *Alpheus praedator* and *A. bidens* have been reported from Madang to the Marshall Islands.

Alpheus pubescens De Man, 1908

Alpheus pubescens De Man, 1908: 109.

Recorded as common in intertidal pools at East Point by Bruce (1988), this species has now also been recorded from Nightcliff Beach and Channel Island. Otherwise known in Australian waters only from two specimens from Torres Strait.

Distribution. Type locality: Kepulauan Aru, and Ujung Pandang, Indonesia. Also known from Vietnam.

Alpheus rapax Fabricius, 1798

Alpheus rapax Fabricius, 1798: 405.

Specimens of this species from Darwin Harbour are currently under study by Dr Y. Miya. Not previously reported from the Northern Territory.

Alpheus serenei Tiwari, 1963

Alpheus serenei Tiwari, 1963: 314-315.

Two pairs of specimens have been collected from Channel Island, possibly in association with *Macrophiothrix* sp. (Ophiuriodea). The species has not been previously recorded from Australian waters.

Distribution. Type locality: Cauda, Vietnam. Also known from the Xi Sha Islands, China.

Alpheus stephensoni Banner and Smalley, 1969

Alpheus stephensoni Banner and Smalley, 1969: 43-47, fig. 2.

A single example has been collected from Channel Island and was identified by Dora May Banner, together with a specimen from Kings Creek, Shoal Bay. Otherwise known only from the type locality.

Distribution. Type locality: Moreton Bay, Queensland. Not known from outside Australian waters.

Alpheus strenuus Dana, 1852

Alpheus strenuus Dana, 1852b: 543, pl. 34, fig. 4.

First reported from Darwin by Banner and Banner (1982). Previously reported from East Point (Bruce 1988), now also known from Bullocky Point. Specimens referrable to the subspecies *A. s. cremnus* Banner and Banner (1982), who also recorded its presence in Darwin, have been collected from Bullocky Point and Casuarina Beach. The two subspecies appear to occur commonly all around Australia.

Distribution. Type locality: Tongatapu, Tonga Islands. Also common throughout the whole Indo-West Pacific region with the exception of the Hawaiian Islands. The *cremnus* subspecies is not known outside Australian waters.

Alpheus ? tasmanicus Banner and Banner, 1982

Alpheus tasmanicus Banner and Banner, 1982: 215-217, fig. 67.

This species is apparently known only from the holotype specimen from an uncertain locality in Tasmania. Not previously reported from the Northern Territory. Specimens from Darwin Harbour are presently under study by Dr Y. Miya.

Distribution. Type locality: Tasmania.

Athanas dimorphus Ortmann, 1894

Athanas dimorphus Ortmann, 1894: 12, pl. 1.

First reported from Darwin by Banner and Banner (1973a). Previously recorded from East Point (Bruce 1988), further specimens have also now been collected from Bullocky Point and Lee Point. Also known from Perth, Western Australia, and from Yeppoon, Queensland, to Sydney, New South Wales.

Distribution. Type locality: Upangi Reef, Dar es Salaam, Tanganyika. Also known from the Red Sea, East Africa, Hong Kong, Japan, the Philippines and New Caledonia.

Athanas haswelli Coutière, 1908

Athanas haswelli Coutière, 1908: 2.

Specimens of this species from Darwin Harbour are presently under study by Dr Y. Miya. Not previously reported from the Northern Territory.

Athanas japonicus Kubo, 1936

Athanas japonicus Kubo, 1936: 43, pl. 8.

Previously recorded from Darwin by Banner and Banner (1973a), the single specimen was the only known Australian example of this species. Numerous examples have now been collected from Bullocky Point, Channel Island, and the mouth of the Blackmore River.

Distribution. Type locality: Mitajiri, Yamaguchi Prefecture, Japan. Known only from Japan and Australia.

Athanas ornithorhynchus Banner and Banner, 1973

Athanas ornithorhynchus Banner and Banner, 1973a: 219-221, fig. 8.

Previously reported from East Point (Bruce 1988), no further specimens have been collected. Otherwise known in Australia only from the type material, four specimens from Van Diemen Gulf, Northern Territory, and from Shark Bay and Cockburn Sound, Western Australia.

Distribution. Type locality: Chambers Bay, Van Diemen Gulf, Northern Territory. Also known only from Hong Kong.

Athanas parvus De Man, 1910

Athanas sibogae De Man, 1910: 314.
Athanas parvus De Man, 1910: 315.

Previously noted as abundant at East Point (Bruce 1988), further specimens have been collected from Bullocky Point, Channel Island, East Arm boat ramp, and Woods Inlet. Also known from Dampier to Rockingham, Western Australia, Torres Strait, Whitsunday Islands and Capricorn Islands, Queensland. Johnson (1976) considers that *A. parvus* and *A. sibogae* are distinct species, but does not state the differences. Most recent authors, e.g. Banner and Banner (1973a) and Chace (1988), appear to treat them as synonymous, whichever name they give priority.

Distribution. Type locality: Timor, Indonesia, 8°39.1'S, 127°4.4'E. Also known from the Red Sea, East Africa, Madagascar, Singapore, Japan, the Philippines, Tonga and Samoan Islands.

Athanas polymorphus Kemp, 1915

Athanas polymorphus Kemp, 1915: 295-299, figs 31-32.

Specimens referred to this species have been collected from Channel Island. Further examples of this species from Darwin Harbour are currently under study by Dr Y. Miya. The species has not been previously reported from Australian waters.

Distribution. Type locality: Chilka Lake, Orissa, India. No further records.

Athanas sp. nov.

Specimens of this species from Darwin Harbour are currently under study by Dr Y. Miya.

Automate dolichognatha De Man, 1888

Automate dolichognatha De Man, 1888b: 529, pl. 52 fig. 5.

Not previously reported from the Northern Territory, a few specimens referred to this species have been collected from Bullocky Point and Weed Reef. Otherwise reported only from the Whitsunday and Capricorn Islands, Queensland.

Distribution. Type locality: Djaga Utara Island (?), off Java, Indonesia. Pantropical, excluding the eastern Atlantic: Red Sea, Djibuti, Kenya, Zanzibar, Madagascar, La Réunion, Maldive Islands, Laccadive Islands, Malaysia, Japan, and from the Mariana Islands to Samoan Islands.

Potamalpheops darwiniensis Bruce, 1993

Potamalpheops darwiniensis Bruce, 1993b: 698-704, figs 1-3.

A single example was collected from Hudson's Creek. No further specimens have been obtained.

Distribution. Type locality: Hudson's Creek, Darwin Harbour, Northern Territory. Not known outside Australian waters.

Potamalpheops hanleyi Bruce, 1991

Potamalphops hanleyi Bruce, 1991: 629-635, figs 1-4.

The type specimens were collected from Creek "H", East Arm of Darwin Harbour. There have been no further records of this species.

Distribution. Type locality: Creek "H", Darwin Harbour, Northern Territory. Not known outside Australian waters.

Pseudathanas darwiniensis Bruce, 1983

Pseudathanas darwiniensis Bruce, 1983c: 464-470, figs 1-5.

Type specimens collected from East Point reef (Bruce 1983c) and reported as common in silty pools in Darwin Harbour (Bruce 1988). Also occurring at Bullocky Point and Channel Island only.

Distribution. Type locality: East Point, Darwin Harbour. Not known outside Australian waters.

Salmoneus sp. nov? (*cf. tafaongae*?)

One ovigerous female has been collected from Bullocky Point and numerous specimens of this species from elsewhere in Darwin Harbour are currently under study by Dr Y. Miya.

Synalpheus comatularum (Haswell, 1882)

Alpheus comatularum Haswell, 1882: 762.

Synalpheus comatularum – Potts 1915: 18, fig. 1.

Not previously reported from Darwin Harbour, one specimen has been obtained from off Elliot Point. Also known from Busselton to Broome, Western Australia, and Torres Strait to Cape Grenville, Queensland.

Distribution. Type localities: Albany Island, Warrior Reef, Prince of Wales Channel, and Thursday Island, Queensland. Also known from Sri Lanka and Singapore.

Synalpheus gracilirostris De Man, 1910

Synalpheus gracilirostris De Man, 1910: 291.

Not previously recorded from Darwin Harbour, specimens have been obtained from Weed Reef and from the wreck of the *Mauna Loa*. Also known only from the Whitsunday Islands, Queensland.

Distribution. Type locality: off north-eastern Timor, Indonesia. Also known from the Red Sea, eastern Africa, La Réunion, Mauritius and the Philippines.

Synalpheus harpagatrus Banner and Banner, 1975

Synalpheus harpagatrus Banner and Banner, 1975: 311-312, fig. 9.

A pair of specimens have been collected from an unidentified sponge host collected from about 5m from Fort Hill Wharf, Darwin Harbour. This species has not been previously recorded from Darwin Harbour or the Northern Territory. Otherwise known only from between Fremantle and Geraldton, Western Australia, and possibly from South Australia.

Distribution. Type locality: North Beach, Perth, at 15 m. Not known outside Australian waters.

Synalpheus iocosta De Man, 1909

Synalpheus iocosta De Man, 1909: 119.

Previously reported from Darwin Harbour (Bruce 1988), in association with the bryozoan *Tryphyllozoon* sp., specimens have also been collected from the wreck of the *Mauna Loa* in Darwin Harbour. Also known from Cape Naturaliste to Carnarvon, Western Australia, and from the Gulf of Carpentaria.

Distribution. Type locality: type series from 12 localities in Indonesia. Also known from the south-eastern South China Sea and the Philippines.

Synalpheus neomeris (De Man, 1888)

Alpheus neomeris De Man, 1888a: 272.

Synalpheus neomeris – Coutière 1905: 869, fig. 1.

Previously noted as abundant in nephtheid alcyonaceans around East Point (Bruce 1988), specimens have also been collected from Casuarina Beach and from Woods Inlet. Also known from Houtman Abrolhos Islands and from Busselton to Cape Carnarvon, Western Australia, Gulf of Carpentaria and Torres Strait, and the Herald Islands, and from Princess Charlotte Bay to the Great Sandy Strait, Queensland.

Distribution. Type locality: Mergui Islands, Burma. Also known from the Red Sea, East Africa, Persian Gulf, Thailand, Indonesia, Japan and the Philippines.

*Synalpheus neptunus (*Dana, 1852)

Alpheus neptunus Dana, 1852b: 553: pl. 35, fig. 5.

Synalpheus neptunus – Coutière 1909: 87, fig. 53.

Not previously recorded from Darwin Harbour, specimens have been collected from a sponge host at Channel Island. Also known from Perth to Exmouth Gulf, Western Australia, Thursday Island, and from Port Douglas, Queensland, to Sydney, New South Wales.

Distribution. Type locality: Sulu Sea; Tictabon Island, near Zamboanga, the Philippines (neotype). Also known from the Red Sea to Japan and Indonesia. Banner and Banner (1975) consider the older records of this species to be unreliable.

Synalpheus pococki Coutière, 1898

Synalpheus neomeris var. *pococki* Coutière, 1898b: 167, fig. 2.

Synalpheus pococki – De Man 1911: 234, fig. 32.

Previously reported from Darwin Harbour by Banner and Banner (1975), further specimens have been collected from a sponge host off the wreck of the *Mauna Loa*. Also known from Torres Strait.

Distribution. Type locality: Holothuria Bank, Timor Sea, and Macclesfield Bank, Arafura Sea (?). Also known only from Kepulauan Aru, Indonesia.

Synalpheus stimpsoni (De Man, 1888)

Alpheus stimpsoni De Man, 1888b: 13, pl. 22, fig. 3.

Synalpheus stimpsoni – Banner & Banner 1966: 46, fig. 12.

Previously reported as a common associate of crinoid hosts at East Point (Bruce 1988), now also known from Elliot Point, Nightcliff Beach, Weed Reef, Channel Island and Channel Rock. Also known "from Sydney, New South Wales, northward along the Great Barrier Reef, across northern Australia and south as far as 37°S in Western Australia" (Banner and Banner 1975).

Distribution. Type locality: Ambon. Indonesia. Also known from East Africa, Madagascar, to Singapore, Thailand, Indonesia, Japan, the Philippines, Loyalty Islands, Marshall Islands and Kiribati.

Synalpheus streptodactylus (Coutière, 1905)

Synalpheus streptodactylus Coutière, 1905: 870, fig. 1.

Previously recorded from East Point (Bruce 1988), further specimens have been reported from off Nightcliff, and Channel Island. Also known from "all coasts of Australia" (Banner and Banner 1975).

Distribution. Type locality: Three localities in the Maldive Islands. Also known from the Red Sea, East Africa, to South Africa, east to Indonesia, Thailand, Japan, the Philippines to Hawaii.

Synalpheus theano De Man, 1910

Synalpheus theano De Man, 1910: 296.

First reported from Darwin Harbour by Banner and Banner (1975), two further lots of specimens have been collected from East Point and Woods Inlet. Also known from near Perth, Western Australia, Thursday Island, and from the Whitsunday Islands, Queensland, to Sydney, New South Wales.

Distribution. Type locality: between Pulau Misool and Pulau Salawati, Indonesia. Also known from the Philippines.

Synalpheus tumidomanus (Paulson, 1875)

Alpheus tumidomanus Paulson, 1875: 101, pl. 13, fig. 2.

Synalpheus tumidomanus — Coutière 1905: 876, pl. 73, fig. 14.

Not previously recorded from Darwin Harbour, specimens have been collected from Stokes Hill Wharf, Woods Inlet, and Channel Island. Also known from "all shores of Australia and at Norfolk Island and Lord Howe Island, Tasman Sea" (Banner and Banner 1975).

Distribution. Type locality: Red Sea. Also known from the Red Sea, East Africa, east to Indonesia, Japan, the Philippines, across Pacific to Phoenix Islands and in the eastern Mediterranean Sea.

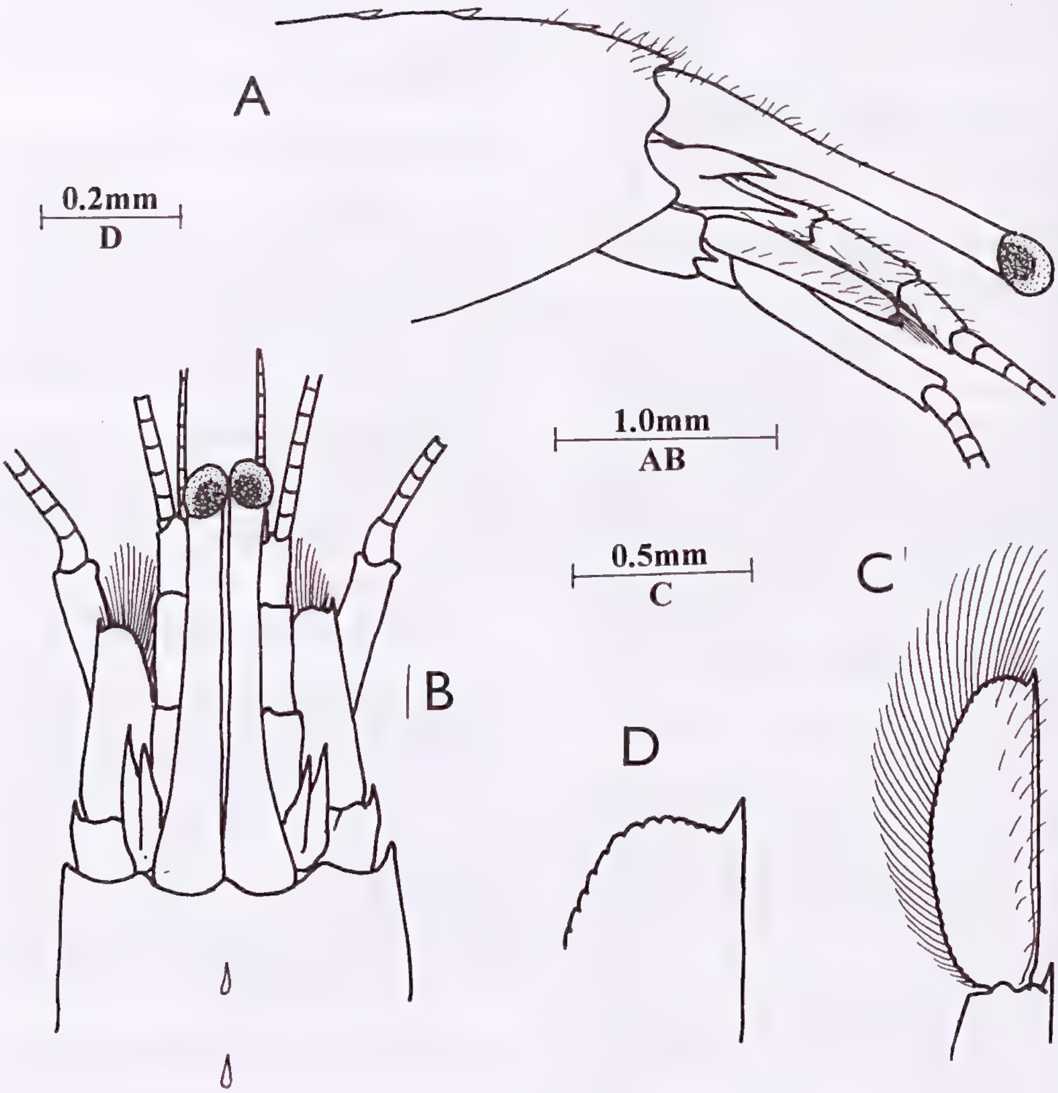

Fig. 8. *Ogyrides mjobergi* Balss, female, Casuarina Beach, Darwin Harbour. **A**, anterior carapace, eye and antennal peduncles, lateral. **B**, same, dorsal. **C**, scaphocerite. **D**, same, distal margin of lamella.

OGYRIDIDAE Hay and Shore, 1918
Ogyrides mjobergi (Balss, 1914)
(Fig. 8)

Ogyris mjöbergi Balss, 1914: 7-9, figs 1-2.
Ogyrides mjobergi — Holthuis and Gottlieb 1958: 48, fig. 10.

A single female was collected from Casuarina Beach (13 September 1981, NTM Cr.000999). This species has not been previously reported from the Northern Territory, and is known in Australian waters only from the type locality at Cape Jaubert, Western Australia, where two specimens were collected in 1911. The specimen (Fig. 8a) has a carapace length of 3.7 mm and agrees closely with the data provided by Banner and Banner (1982). The rostrum (Fig. 8b) is very short and does not exceed the lateral orbital angles; the carapace bears three articulated post-rostral spines; the eye stalk appears straighter than in the type material, less swollen proximally, and far exceeding the end of the carpocerite, which also distinctly exceeds the end of the antennular peduncle; the basicerite has an acute lateral tooth not mentioned but figured by Balss (1914); the scaphocerite (Fig. 8c) reaches to about 0.6 of the eye stalk length and bears a small acute distolateral tooth (Fig. 8d), which clearly exceeds the anterior margin of the lamella; the carpus of the second pereiopod is four-segmented.

Banner and Banner (1982) considered it quite probable that *O. mjobergi* would eventually prove to be a junior synonym of *O. orientalis* (Stimpson), described in 1860 from Hong Kong. Comparison of the present specimen with the specimen of that species from Hong Kong described by Bruce (1990) confirms that the two species are distinct. In *O. orientalis* the eyestalks similarly exceed the antennular peduncles and carpocerite, but are much more attenuated, with more conspicuously swollen bases, the rostrum is more acute, strongly produced, far exceeding the lateral orbital angles, the scaphocerite has the distal lamella strongly and angularly produced, far exceeding the tip of the distolateral spine, the anterolateral angle of the branchiostegite also appears much less produced

It is interesting that, although the eyestalks in preserved *Ogyrides* spp are usually in a depressed attitude, the eyestalks appear to have little mobility and will not flex dorsally as might be expected in a silt burrowing animal. Possibly they maintain an attitude with the ventral aspect of their body uppermost when buried. There appear to be no observations on living *Ogyrides* species.

The material described from Tuléar, Madagascar, by Ledoyer (1968) differs from the present specimen in the shape of the scaphocerite, in which the lamella is attenuated distally and distinctly exceeded by the distolateral tooth.

Distribution. Type locality: Cape Jaubert, Western Australia, at 17 m. Also reported from Madagascar (?) and from the eastern Mediterranean Sea.

HIPPOLYTIDAE Bate, 1888

Gelastocaris paronae (Nobili, 1905)

Latreutes paronae Nobili, 1905: 2-3, 1 fig.

Gelastocaris paronae — Kemp 1914: 107, pl. 5.

Previously reported from East Point by Bruce (1988), further specimens have been obtained from Weed Reef. Also recorded from Cape Jaubert, Western Australia.

Distribution. Type locality: Zanzibar. Also known from Sri Lanka, Andaman Islands, Singapore, Indonesia and New Caledonia.

Hippolyte ventricosa H. Milne Edwards, 1837

Hippolyte ventricosus H. Milne Edwards, 1837: 371.

Previously reported from East Point by Bruce (1988), further material has been collected from Nightcliff Beach, Lee Point and Channel Island. Also known from Queensland, New South Wales, South Australia and Western Australia.

Distribution. Type locality: "les Mers d'Asie". Also known from the Red Sea, East Africa, south India to Hawaii.

Hippolyte sp. nov?

A single lot of specimens has been collected from Dudley Point.

Latreutes anoplonyx Kemp, 1914

Latreutes anoplonyx Kemp, 1914: 104, pl. 4, figs 3-5.

Specimens have recently been reported from Buffalo Creek and three miles north of Darwin Harbour wharves, in association with jellyfish of the genera *Phyllorhiza* and *Versuriga* (Bruce 1995).

Distribution. Type locality: Bombay, India. Also known from Burma, Malaya, Indonesia, China and Japan.

Latreutes mucronatus (Stimpson, 1860)

Rhynchocyclus mucronatus Stimpson, 1860: 95.

Latreutes mucronatus – Balss 1914: 47, fig. 27.

Previously reported from East Point by Bruce (1988), further material has been collected from Fannie Bay and Nightcliff Beach. Previously reported from Cape Jaubert, Western Australia, and the Low Isles, Queensland.

Distribution. Type locality: Hong Kong. Also known from the Red Sea, Djibuti, off Yemen, South Africa, south India, Andaman Islands, Indonesia, Korea, China, Japan and New Caledonia.

Latreutes porcinus Kemp, 1916

Latreutes porcinus Kemp, 1916a: 397-398, fig. 3, pl. 36.

Not previously recorded from Darwin Harbour, two lots of specimens have been collected from Nightcliff. Also known from Moreton Bay, Queensland(?).

Distribution. Type locality: Port Blair, Andaman Islands. Also known from Singapore and Japan.

Lysmata vittata (Stimpson, 1860)

Hippolysmata vittata Stimpson, 1860: 26.

Previously reported from East Point by Bruce (1988), further specimens have been collected from Bullocky Point, Fannie Bay, Ludmilla Creek, Lee Point, King Creek and Shoal Bay. Also known from the Low Isles and Moreton Bay, Queensland.

Distribution. Type locality: Hong Kong. Also known from the Red Sea, Kenya, South Africa, Madagascar, Thailand, Malaya, Singapore, Indonesia, Korea, Japan, the Philippines and New Caledonia.

Lysmatella sp.

A single male example has been collected from Woods Inlet, from 3-5 m. This genus has not been previously recorded from Australian waters. The specimen appears readily distinguishable from *L. prima* Borradaile (1915), having a much shorter rostrum with seven dorsal and three ventral rostral teeth only. Johnson (1976) reports that *L. prima*, which has been found on the Northwest Shelf, may be associated with subtidal actinarians.

Chace (pers. comm.) does not recognise the subgenus *Lysmatella*, which Holthuis (1955) distinguishes from *Lysmata* by the lack of epipods on the pereiopods. The discovery of a second species with this character suggests that it may have some validity. In *Lysmata* epipods are present on each of the first four pairs of pereiopods.

Phycocaris simulans Kemp, 1916

Phycocaris simulans Kemp, 1916a: 392-396, fig. 2, pl. 36.

Previously reported from East Point by Bruce (1988), this species has now also been recorded from Bullocky Point, Lee Point and Gunn Point. Also known from Heron Island, Queensland.

Distribution. Type locality: Port Blair, Andaman Islands. Otherwise known only from Madagascar.

Saron marmoratus (Olivier, 1811)

Palaemon marmoratus Olivier, 1811: 663.

Saron marmoratus – Ortmann 1894: 15.

Previously reported from East Point by Bruce (1988), no further examples have been collected. Also known from Northwest Island, Queensland, and other Great Barrier Reef localities.

Distribution. Type locality: "Australie". Common and widespread on coral reefs throughout the whole Indo-West Pacific region from the northern Red Sea to Hawaii.

Thor amboinensis (De Man, 1888)

Hippolyte amboinensis De Man, 1888b: 535.

Thor amboinensis – Holthuis 1947: 50.

Not previously recorded from Darwin Harbour, one specimen only has been collected only from 8-10 m at Weed Reef. Common on the Great Barrier Reef in association with a variety of coelenterates, there appear to be few published Australian records of this species.

Distribution. Type locality: Ambon, Indonesia. Also reported from Kenya, Madagascar, Andaman and Nicobar Islands, Ryukyu Islands, Japan and Caroline Islands.

Thor paschalis (Heller, 1862)

Hippolyte paschalis Heller, 1862: 276, pl. 3, fig. 24.

Thor paschalis – Kemp 1914: 94, pl. 1, figs 6-10.

Previously reported from East Point by Bruce (1988), specimens have now also been obtained from Nightcliff Beach, Lee Point and Channel Island. Also known from Rottnest Island, Western Australia, and from the Low Isles, Queensland.

Distribution. Type locality: Red Sea. Also known from Kenya, Zanzibar, Madagascar, south India, Singapore, Indonesia, Japan, Mariana Islands and New Caledonia. Also recorded from the American west coast.

Thor spinipes Bruce, 1983

Thor spinipes Bruce, 1983a: 2-9, figs 1-6.

Previously reported from East Point by Bruce (1988), further examples have been collected from Nightcliff Beach, Ludmilla Creek, Lee Point and Channel Island. Not yet known outside the Northern Territory.

Distribution. Type locality: Burford Island, Cobourg Peninsula, Northern Territory. Not yet known outside Australian waters.

Thorella cobourgi Bruce, 1982

Thorella cobourgi Bruce, 1982: 452-458, figs 1-5.

Not previously recorded from Darwin Harbour, specimens have been collected from Bullocky Point, Dudley Point, Channel Island and the East Arm of Darwin Harbour. Not known from outside the Northern Territory.

Distribution. Type locality: Black Point, Port Essington, Cobourg Peninsula, Northern Territory. Not yet known outside Australian waters.

Tozeuma armatum Paulson, 1875

Tozeuma armatum Paulson, 1875: 99, pl. 15, figs 2, 2a-d, f-h, k, m-o.

Previously reported from East Point by Bruce (1988), no further examples have been subsequently collected.

Distribution. Type locality: Red Sea. Also reported from Moçambique, Madagascar, Sri Lanka, south India, Andaman Islands, Burma, Indonesia, Japan and New Caledonia.

PROCESSIDAE Ortmann, 1896

Processa demani Hayashi, 1975

Processa demani Hayashi, 1975: 98-102, figs 19-20.

Not previously recorded from Darwin Harbour, a single specimen has been collected from the Weed Reef area. No previous Australian records.

Distribution. Type locality: Great Kei Island, Indonesia. Also known from Vietnam.

Processa dimorpha Hayashi, 1975

Processa dimorpha Hayashi, 1975:102-106, fig. 21.

Not previously recorded from Darwin Harbour, specimens have been collected from Creek "H". Previously reported only from Moreton Bay, Queensland.

Distribution. Type locality: Sea of Genkai, Fukuoka, Japan. Also known from Vietnam.

Processa sulcata Hayashi, 1975

Processa sulcata Hayashi, 1975: 134-137, fig. 34.

Previously reported from East Point by Bruce (1988), no further examples have been subsequently collected from Darwin Harbour. Also reported only from Moreton Bay, Queensland .

Distribution. Type locality: Ainoshima Island, Fukuoka, Japan. Also known from South Africa, Madagascar, Indonesia, Vietnam and the Philippines.

PANDALIDAE Dana, 1852

Chlorotocella gracilis Balss, 1914

Chlorotocella gracilis Balss, 1914: 33, figs 16-22.

First recorded in Australian waters from four specimens collected from East Point on a gorgonian *Junceella fragilis* from 13 m (Bruce 1988), further specimens have now been collected from Fannie Bay, Elliot Point, Channel Island, Woods Inlet, and north west of Middle Point. Probably common and widespread in Australian waters but as yet only recorded twice from the Northwest Shelf, Western Australia, and Moreton Bay, Queensland.

Distribution. Type locality: Sagami Bay, Japan. Also known from the Andaman and Nicobar Islands, Singapore, Indonesia, the Philippines and New Caledonia.

CRANGONIDAE Haworth, 1825

The following species have been identified from Darwin Harbour by S. de Grave, and will be reported on in detail elsewhere: *Philocheras pilosus* (Kemp, 1916b); *Philocheras ? obliquus* (Fulton and Grant, 1902); *Philocheras* sp. nov., cf. *angustirostris* (De man, 1920); *Philocheras* ?sp. nov. 1; *Philocheras* ?sp. nov. 2.

DISCUSSION

Comparisons of the caridean fauna of Darwin Harbour with those of other regions are difficult as detailed inventories for other localities in the tropical Indo-West Pacific region are few, and the locations are frequently not closely similar in scope or habitats. The two focal studies that are most appropriate for comparison with the Darwin Harbour fauna is that of Amakusa Island, in southern Japan (Kikuchi and Miyake 1978) and that of the Singapore fauna (Johnson 1976). Both these localities differ from Darwin Harbour in that coral reefs are moderately or well represented in the available biotopes. The coral reef habitat is poorly represented in Darwin Harbour and has only been sparsely and inadequately sampled. Consequently the suite of coral-associated species is largely conspicuous by itsabsence from the fauna of Darwin Harbour. The Singapore fauna also appears to include a component of deeper water, trawl-caught species from as deep as 170m. These are not as yet known from Darwin Harbour, although further sampling may reveal the presence of some of them in the deeper central waters. There are no suitable comparable studies of other tropical (or non-tropical) Australian localities.

The Darwin Harbour fauna has a similar species diversity to that of Singapore, with some 121 species compared to 132 species. Due to certain taxonomic uncertainties in both species lists an exact enumeration can not be given. Of these, 51 species occur in both regions, some 39% of the Darwin Harbour fauna. The Amakusa Island fauna is represented by 91 species, of which only 21 species are also found in Darwin Harbour (17.4% of the Darwin Harbour species).

At generic level, the Darwin Harbour fauna is represented by 35 genera, Singapore by 46 and Amakusa Island by 34 genera. Of the total 66 genera represented at these localities, 19 genera (29.2%) occur in all three. With Singapore only, 28 genera (80%) occur in common with Darwin Harbour. Only a single genus, *Ogyrides*, occurs in Darwin Harbour and on Amakusa Island but is not yet reported from Singapore.

Of the 121 species reported from Darwin Harbour, 37 (30.5%) are known or considered to be obligatory associates of other marine animals, 22 of these belonging to the subfamily Pontoniinae.

The palaemonoid shrimp fauna of the Cobourg Peninsula, principally of Port Essington, has been studied (Bruce and Coombes 1995), and may be compared with the palaemonoid fauna of Darwin Harbour. Forty species have been so far collected from Darwin Harbour. Sixty-one species were recorded from the Cobourg Peninsula., of which 45 occur in Port Essington itself (not including Orontes Reef), which may be considered to be basically similar in its major biotopic features to Darwin Harbour. Twenty-six of the Darwin Harbour palaemonoids have also been collected from the Cobourg Peninsula. Of the 46 species that have been collected from Port Essington, 23 have not been found as yet in Darwin Harbour. Conversely, of the 40 species known in Darwin Harbour, 15 are not known as yet from Port Essington or the Cobourg Peninsula. Many of the species missing from the Darwin Harbour fauna are the coral-associated species found on the more extensively developed coral reef formations of the Cobourg Peninsula region.

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DARWIN HARBOUR FISHES: A SURVEY AND ANNOTATED CHECKLIST.

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ABSTRACT

An annotated checklist of Darwin Harbour fishes is presented, which includes 31 new records from the Northern Territory, three of which were collected during a beam trawl survey of the benthic fish fauna in Darwin Harbour as part of the Sixth International Marine Biological Workshop, held in June-July, 1993. A total of 75 species were recorded from the survey. To this were added previous literature records of Darwin Harbour fish species, and species held in the Museum and Art Gallery of the Northern Territory's collection of fishes, to give 415 species now known from the Harbour.

KEYWORDS: Northern Territory, Darwin Harbour, fish species, new records, type locality, checklist.

INTRODUCTION

It is somehow appropriate that the company of HMS *Beagle* made the first scientific collection of fishes from Darwin Harbour, in September, 1839. Lt James Emery made the first collections and drawings of six species of fishes from Talc Bay (= Talc Head, where he spent nine days digging a well). Richardson (1842, 1843) used Emery's drawings as the basis for his description of two new species, the first described from the Harbour: *Platax leschenaldi* Richardson, 1842 (= *Platax teira*), and *Maenoides? auro-frenatus* Richardson, 1843 (= *Pentapodus porosus*).

The first attempt at a summary of Darwin Harbour fishes was Macleay's 1878 *Fishes of Port Darwin*, which reported 114 species from the Harbour, 21 of which were new. Klunzinger (1879) reported on the fishes of Port Philip (Victoria) and Port Darwin sent to Stuttgart by Ferdinand von Müller during 1871-2. He recorded 46 species from the Harbour, eight of which he described as new. Paradice and Whitley (1927) recorded 34 species and described one new species from Port Darwin, which were collected by Navy medical officers W.E.J. Paradice (1923 to 1924) and K.E.F.D. Hudson (during 1925). Taylor (1964) recorded 12 species from Darwin Harbour in his *Fishes of Arnhem Land* and described a new species partly based on Darwin Harbour material. The most recent attempt to summarise the Darwin Harbour fish fauna was that of Larson (1988), who recorded 408 nominal species from the harbour and estimated that 340 of these (comprising 95 families) were probably valid. The fishes of Darwin Harbour are almost as well known as the fishes of Port Essington. The Port Essington area has been sampled with some effort by NTM biologists since 1981 (Larson and Russell, in prep).

A beam trawl survey of 40 stations within Darwin Harbour was made as part of the Sixth International Marine Biological Workshop held in Darwin from 5 to 23 July, 1993. The survey, although limited to beam trawling, collected three new records for the Northern Territory. It was considered worthwhile to combine the results of the survey with literature records kept by Larson as part of a checklist (in preparation) of all Northern Territory fishes, and records of specimens housed at the Museum and Art Gallery of the Northern Territory (NTM). Since the establishment of the Museum at its present site in 1981, regular collections have been made by

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the authors at a number of sites within the harbour, mostly using rotenone and scoopnets.

Beam trawl survey methods. Forty stations (Fig.1) in the harbour were sampled with a 2-metre wide beam trawl (12 mm mesh size body and 3 mm mesh size cod end) towed for 10 minute intervals against the tidal flow. Trawl samples were restricted to localities where depth was 12 m or less and known to be free of rocky reef (some parts of the inner harbour are 20 m or more; the outer harbour has areas 33 m deep). Sampling sites were those shown in Frontispiece. However, due to local weather conditions (seasonal strong winds) and logistics, it was not possible to sample all trawl stations during the workshop, and samples were taken at four different times. Twenty-five sites were sampled from 6-16 July, three sites on 9 September and four on 7 December. On 21 March, five trawls were made off Casuarina Beach, with only one station yielding any fish. Four trawls were made on 5 April and a final three on 18 April.

Trawl survey results. The general type of substrate and benthic organisms present at each station are recorded in Table 1. Due to the nature of the beam trawl, substrate was sampled less often than the organisms upon it. Mud and muddy or shelly sand were the substrate types most often recorded, and sponges, soft corals and algae were the predominant organisms.

Table 2 shows fish species, subtrate type and associated benthic organisms present at each station. As may be expected, several species were found in specific habitats; e.g. cynoglossids found with sand, muddy sand or mud, and the gobiids *Amoya, Butis* and *Drombus* usually associated with mangrove detritus (e.g. leaves, pneumatophores). A few species appear in many of the stations, such as *Apogon rueppellii, Butis koilomatodon* and *Monacanthus chinensis* and *Paramonacanthus choirocephalus* (which appeared in nearly half the stations). *Paramonacanthus choirocephalus* also was associated with the widest range of substrates and other organisms (Table 2). The fishes in Table 2 are a mixture of shallow inshore reef species and species which are more usually caught off-shore in deeper waters, reflecting the range of habitats sampled (river estuaries, mud and sand flats, and deeper water slopes).

Although the trawls were conducted at different times and during different seasons, no clear seasonal differences in species composition are evident. Length frequencies for fish caught in the July and September/December periods were compared, to determine any seasonal variation between species. Only *Terapon puta* and *Pelates quadrilineatus* showed any size increase over the survey period; all other species averaged about the same length.

ANNOTATED CHECKLIST OF DARWIN HARBOUR FISHES

The checklist includes only abbreviated literature records; original references for some species have not been sighted. A complete checklist of Northern Territory fishes is in preparation by Larson. Marine and estuarine fishes only are included. Sight records have not been included. The "harbour" is generally taken to be the area below a line drawn from Charles Point to Lee Point (Fig. 1); however, for the purposes of this list, records from Buffalo Creek mouth (just E of Lee Point, Fig. 1) have been included.

In each synonymy, at least the first literature record of each species' occurrence in Darwin or the Northern Territory is given. More than one reference may be given if the species has appeared under a variety of names in the older literature. Additional material listed is based on specimens held in the Fish Collection of the Museum and Art Gallery of the Northern Territory.

AMPHIOXIFORMES

Epigonichthyidae

Epigonichthys cultellus Peters, 1877

Epigonichthys cultellus Peters, 1877: 325 (Peale Island, Moreton Bay, Queensland).

One specimen, S of Dudley Point. This is the first record of this species from the Northern Territory.

LAMNIFORMES

Orectolobidae

Chiloscyllium punctatum Müller and Henle, 1838

Chiloscyllium punctatum Müller and Henle, 1838: 19 (Java). - Klunzinger 1879 (Port Darwin).

Additional material from East Arm, Darwin Harbour.

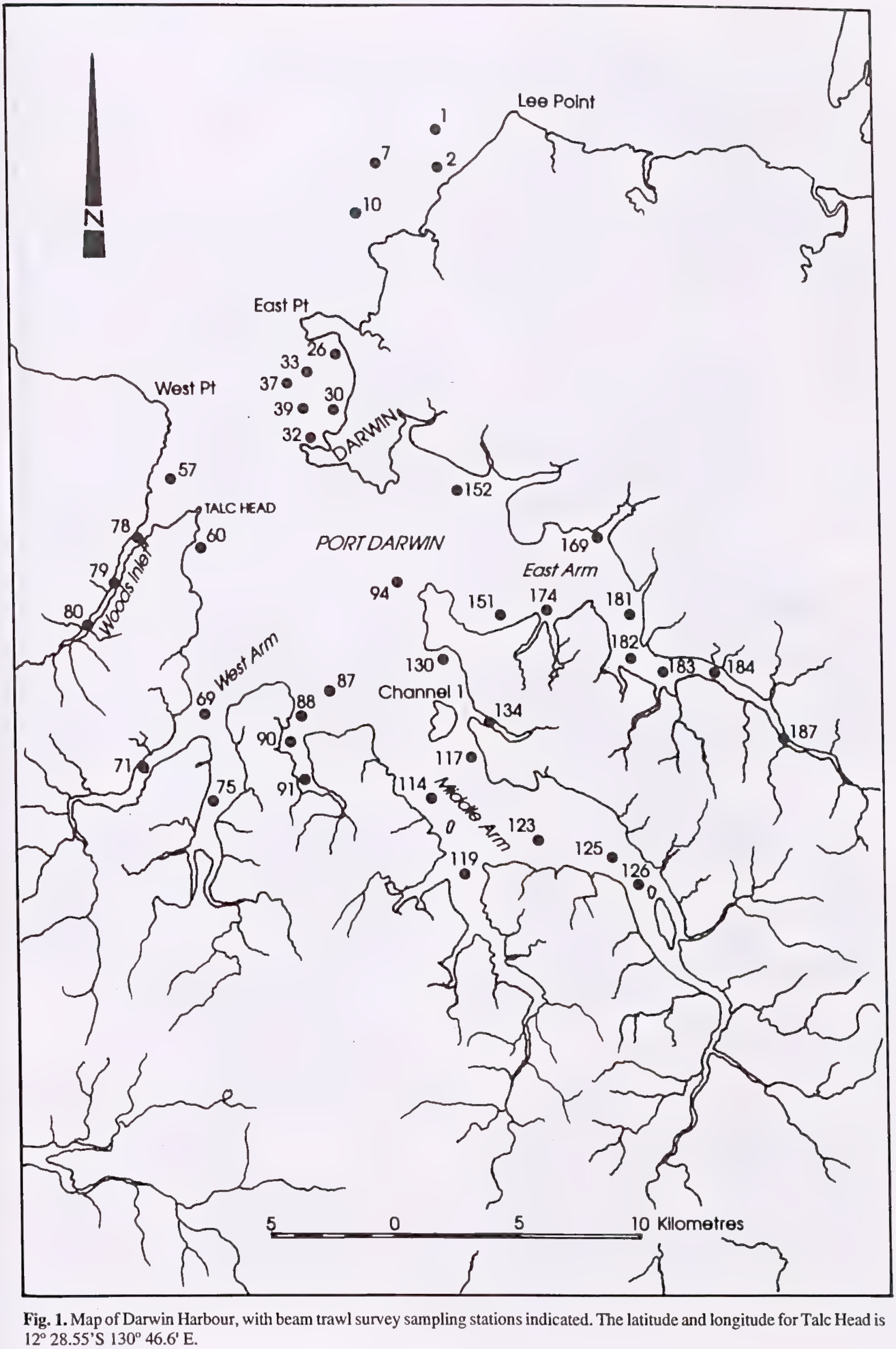

Fig. 1. Map of Darwin Harbour, with beam trawl survey sampling stations indicated. The latitude and longitude for Talc Head is 12° 28.55'S 130° 46.6' E.

Table 1. Substrate type and benthic organisms observed to be pr[illegible] first 25 stations were sampled from 6-16 July, 1993, three on 9 September and four on 7 December. On 21 March, 1994, five trawls were made off Casuarina Beach, with only one station yielding any fish. Four trawls were made on 5 April 1994 and a final three on 18 April 1994.

Stn. No.	ascidians	bryozoans	coral rubble	crinoids	rubble	sand	muddy sand	shelly sand	mangrove detritus	mud	shells	gorgonians	hydroids	algae	soft corals	sponges
1						X										
2						X										
7												X				X
10						X									X	
26							X							X		
30							X							X		
32								X								X
33							X							X		
37													X			X
39								X						X		
57															X	X
60														X	X	X
69													X	X		X
71													X	X		X
75	X												X	X		
78												X			X	X
79												X			X	X
80												X			X	X
87										X					X	X
88					X						X				X	X
90									X		X					
91									X							X
94														X	X	X
114								X								
117										X	X					
119				X											X	X
123										X						
125								X		X						
126									X						X	X
130										X						
134			X											X	X	X
151					X		X				X					
152										X						
169											X			X	X	X
174					X						X				X	X
181				X								X			X	X
182		X										X	X			X
183													X			X
184									X				X			
187									X							

Hemiscyllium ocellatum (Bonnaterre, 1788)

Squalus ocellatus Bonnaterre 1788: 8 ("La mer du sud").
Chiloscyllium ocellatum - Klunzinger 1879 (Port Darwin).

Hemiscyllium trispeculare Richardson, 1843

Hemiscyllium trispeculare Richardson, 1843: 5 (Turtle Island, north-west coast of Australia).
Chiloscyllium trispeculare - Ogilby and McCulloch 1909 (Port Darwin).
Last and Stevens (1994: 136) state that NT specimens differ in colour pattern from WA specimens.

Orectolobus wardi Whitley, 1939

Orectolobus wardi Whitley, 1939: 264 (Cape Keith, Melville Island, NT).
?*Scylliorhinus maculatus* - Ogilby 1889 (Port Darwin).
One specimen from East Arm, Darwin Harbour.

Scylliorhinidae

Atelomycterus macleayi Whitley, 1939

Atelomycterus macleayi Whitley, 1939a: 227 (Port Darwin).
Additional material from East Point, Darwin.

Carcharhinidae

Carcharhinus cautus (Whitley, 1945)

Galeolamna greyi cauta Whitley 1945: 2 (Shark Bay, Herald Bight, Western Australia).
Carcharhinus cautus - Garrick 1982 (Port Darwin).
Additional material from Darwin Harbour.

Carcharhinus dussumieri (Valenciennes, 1839)

Carcharias (Prionodon) dussumieri Valenciennes, 1839: 47 (Pondicherry).
Carcharhinus dussumieri - Paxton *et al.*1989 (NT).
Material from Woods Inlet.

Carcharhinus fitzroyensis (Whitley, 1943)

Galeolamna (Uranganops) fitzroyensis Whitley, 1943: 117 (Connor Creek, Fitzroy River, Queensland).
Carcharhinus fitzroyensis - Compagno 1984 (northern and northwestern Australia). - Lyle 1987 (Darwin Harbour).

Carcharias melanopterus (Quoy and Gaimard, 1824)

Carcharias melanopterus Quoy and Gaimard 1824: 194 (Waigeo Island). - Macleay 1881 (Port Darwin).
Carcharias hemiodon - Macleay 1878 (Port Darwin).
Carcharhinus melanopterus - Lyle 1987 (Darwin Harbour).

Galeocerdo cuvieri (Péron and Lesueur, 1822)

Squalus cuvier Péron and Lesueur, 1822: 343-352 (NW coast of New Holland).
Galeocerdo cuvieri - Lyle and Timms 1987 (Darwin Harbour).

Sphyrnidae

Sphyrna lewini (Griffith and Smith 1834)

Zygaena lewini Griffith and Smith, in Cuvier, Griffith and Smith 1834: 640 (south coast of New Holland).
Sphyrna lewini - Compagno 1984 (NT, map only). - Lyle and Timms 1987 (Darwin Harbour).

RAJIFORMES

Rhynchobatidae

Rhynchobatus djiddensis (Forsskål, 1775)

Raja djiddensis Forsskål, 1775: 18 (Djedda and Red Sea).
Rhynchobatus djiddensis - Russell and Houston 1989 (Arafura Sea).
One specimen from Vesteys Beach.

Rhinobatidae

Rhinobatos typus Bennett, 1830

Rhinobatos typus Bennett, 1830: 694 (Sumatra?). - Last and Stevens 1994 (NT map).
Rhinobatos granulatus - Macleay 1878 (Port Darwin).
Additonal material from East Point Reef and Casuarina Beach.

Table 2. Station numbers, fish species present, and organisms and substrate types associated with each species.

Fish Species	Station Numbers	Substrate, organisms
Atelomycterus macleayi	182	sponges, gorgonians, hydroids
Engraulididae	30	muddy sand, algae
Saurida micropectoralis	30	muddy sand, algae
Batrachomoeus trispinosus	71, 75, 78, 184	mangrove detritus, sponges, algae, hydroids, ascidians, gorgonians, soft corals
Tathicarpus butleri	69, 75	algae, sponges, hydroids, ascidians
Haliichthys taeniophorus	60, 71, 174	rubble, shell, algae, soft corals, sponges
Hippocampus hystrix	182	sponges, gorgonians, hydroids, bryozoa
Hippocampus planifrons ?	126	mangrove detritus, sponges, soft corals
Campichthys tricarinatus	57	sponges, soft corals
Trachyrhamphus longirostris	33, 71, 125	muddy sand, shelly sand, mud, sponges, hydroids, algae
Liocranium praepositum	80, 182	sponges, gorgonians, hydroids, soft corals, bryozoa
Paracentropogon sp.	69	sponges, algae, hydroids
Paraploactis trachyderma	182	sponges, gorgonians, hydroids, bryozoa
Inegocia japonica	33, 57, 80, 94, 151	rubble, shell, sponges, gorgonians, soft corals, algae
Papilloculiceps nematophthalmus	71, 75, 134, 183	coral rubble, soft corals, sponges, hydroids, algae, ascidians
Suggrundus harrisii	10, 33, 71, 119, 125, 183	sand, shelly sand, muddy sand, mud, soft corals, algae, hydroids, sponges, crinoids
Suggrundus sp.1	174	rubble, shell, sponges, soft corals
Suggrundus staigeri	134, 182	coral rubble, sponges, gorgonians, hydroids, bryozoa
Pegasus volitans	169, 174, 181	rubble, shell, sponges, algae, crinoids, soft corals, gorgonians
Centrogenys vaigiensis	71, 94, 134, 169, 174	coral rubble, rubble, shell, sponges, hydroids, algae, soft corals
Epinephelus coioides	88	rubble, shell, soft corals, sponges
Epinephelus sexfasciatus	71, 119	sponges, hydroids, algae, crinoids
Assiculus punctatus	57, 69, 71, 78, 94, 119, 134	coral rubble, sponges, hydroids, algae, gorgonians, soft corals, crinoids
Pelates quadrilineatus	69, 71, 134, 174	coral rubble, rubble, shell, sponges, hydroids, algae, soft corals
Terapon puta	69, 71, 169	shell, sponges, hydroids, algae, soft corals
Apogon albimaculosus	69	sponges, hydroids, algae
Apogon fasciatus	33, 60, 71, 119, 181	muddy sand, algae, soft corals, sponges, hydroids, crinoids, gorgonians
Apogon melanopus	57, 71, 79, 119, 181, 182	sponges, gorgonians, hydroids, algae, soft corals, bryozoa, crinoids
Apogon opercularis	182	sponges, gorgonians, hydroids, bryozoa
Apogon poecilopterus	181	gorgonians, soft corals, sponges, crinoids
Apogon rueppelli	69, 71, 75, 80, 88, 91, 130, 134, 151, 169, 174, 181	mud, muddy sand, mangrove detritus, coral rubble, rubble, shell, sponges, hydroids, algae, ascidians, crinoids, soft corals, gorgonians
Apogon unitaeriatus	33, 57, 60, 69, 169, 181	muddy sand, shell, algae, soft corals, sponges, gorgonians, crinoids
Siphamia roseigaster	60, 71, 80, 119	algae, soft corals, sponges, hydroids, gorgonians, ascidians
Sillago maculata	79, 126, 152	mangrove detritus, mud, soft corals, gorgonians, sponges
Alepes sp.	1	sand
Caranx bucculentus	184	mangrove detritus, hydroids
Leiognathus sp.	30, 33	muddy sand, algae

Table 2, continued.

Fish Species	Station Numbers	Substrate, organisms
Leiognathus moretoniensis	60	algae, soft corals, sponges
Lutjanus malabaricus	32, 60	shelly sand, algae, soft corals, sponges
Pentapodus sp.	57, 78, 134	coral rubble, gorgonians, soft corals, sponges, algae
Lethrinus genivittatus	134	coral rubble, algae, sponges, soft corals
Upeneus sp.	30, 60, 181	muddy sand, algae, soft corals, sponges, crinoids, gorgonians
Parachaetodon ocellatus	80	gorgonians, soft corals, sponges
Choerodon cyanodus	69, 134	coral rubble, hydroids, algae, sponges, soft corals
Choerodon monostigma	37, 69, 71, 134, 174	rubble, shell, coral rubble, sponges, hydroids, algae, soft corals
Congrogadoides spinifer	78	gorgonians, soft corals, sponges
Callionymus grossi	26, 33, 119, 169, 174	muddy sand, rubble, shell, soft corals, crinoids, sponges, algae
Callionymus macdonaldi	91	mangrove detritus, sponges
Callionymus russelli	117, 151, 152, 169, 174	muddy sand, mud, rubble, shell, algae, soft corals, sponges
Callionymus sphinx	33, 39, 60, 181	muddy sand, shelly sand, algae, soft corals, sponges, crinoids, gorgonians
Callionymus sublaevis	69, 114, 126	shelly sand, mangrove detritus, hydroids, algae, sponges, soft corals
Acentrogobius caninus	117, 169	mud, shell, algae, soft corals, sponges
Amoya sp.	91	mangrove detritus, mud
Drombus ocyurus	88, 117, 130, 151, 169, 181	mud, muddy sand, rubble, shell, crinoids. gorgonians, soft corals, sponges, algae
Drombus triangularis	90	mangrove detritus, mud
Favonigobius melanobranchus	26, 30	muddy sand, algae
Gnatholepis sp.	134	coral rubble, algae, soft corals, sponges
Palutrus scapulopunctatus	80	gorgonians, soft corals, sponges
Butis butis	187	mangrove detritus
Butis koilomatodon	57, 78, 79, 119, 134, 174, 182, 183, 184	mangrove detritus, coral rubble, rubble, shell, soft corals, sponges, gorgonians, hrydroids, bryozoa, crinoids, algae
Apocryptodon madurensis	87	mud, soft corals, sponges
Siganus sp.	134	coral rubble, algae, sponges, soft corals
Siganus fuscescens	71	algae, sponges, hydroids
Arnoglossus intermedius	33, 60, 71, 181	muddy sand, sponges, hydroids, algae, crinoids, gorgonians, soft corals
Pseudorhombus elevatus	60, 130, 152	mud, sponges, soft corals, algae
Pseudorhombus jenynsii	134	coral rubble, algae, sponges, soft corals
Dexillichthys muelleri	181	gorgonians, crinoids, soft corals, sponges
Cynoglossus sp.	30, 33, 151	muddy sand, shell, rubble, algae
Cynoglossus maculipinnis	123, 181	mud, sponges, crinoids, gorgonians, soft corals
Cynoglossus puncticeps	33	muddy sand, algae
Paraplagusia bilineata	2	sand
Anacanthus barbatus	60, 94, 174	rubble, shell, algae, soft corals, sponges
Monacanthus chinensis	69, 75, 78, 88, 119, 134, 169, 174, 182	coral rubble, rubble, shell, algae, hydroids, sponges, crinoids, gorgonians, ascidians, soft corals, bryozoa
Paramonacanthus choirocephalus	7, 32, 33, 37, 39, 57, 60, 69, 71, 75, 79, 87, 119, 123, 126, 130, 174, 183, 184	shelly sand, rubble shell, muddy sand, mud, mangrove detritus, algae, crinoids, hydroids, gorgonians, soft corals, sponges, ascidians
Torquigener pallimaculatus	126	mangrove detritus, soft corals, sponges
Tragulichthys jaculiferus	183	sponges, hydroids

Dasyatididae

Dasyatis kuhlii (Müller and Henle, 1841)

Trygon kuhlii Müller and Henle, 1841: 164 (India, Vanikoro, New Guinea).
Amphotistius kuhlii - Paxton *et al.* 1989 (NT).
Additional material from Darwin Harbour.

Dasyatis fluviorum Ogilby, 1908

Dasyatis fluviorum Ogilby, 1908: 6 (Brisbane River). - Last and Stevens 1994 (Darwin).

Pastinachus sephen (Forsskål, 1775)

Raja sephen Forsskål, 1775: 17 (Djedda, Red Sea).
Dasyatis sephen - Paxton *et al.* 1989 (NT).
Material from off East Arm Quarantine Station and Rapid Creek.

Himantura sp. A

Himantura sp. A - Last and Stevens 1994 (Darwin).

Himantura granulata (Macleay, 1883)

Trygon granulata Macleay, 1883: 598 (Port Moresby).
Himantura granulata - Paxton *et al.* 1989 (NT).
Material from East Arm.

Himantura uarnak (Forsskål, 1775)

Raja uarnak Forsskål, 1775: 18 (Loheia, Red Sea).
Trygon uarnak - Macleay 1878 (Port Darwin).
Material from off Mindil Beach.

Taeniura lymma (Forsskål 1775)

Raja lymma Forsskål 1775: 17 (Loheia, Red Sea).
Taeniura lymma - McCulloch 1920 (Port Darwin).

Myliobatidae

Aetobatus narinari (Euphrasen, 1790)

Raja narinari Euphrasen, 1790: 217 (West Indies).
Aetobatus punctatus - Whitley 1940 (Port Darwin).

ELOPIFORMES

Elopidae

Elops hawaiiensis Regan, 1909

Elops hawaiensis Regan, 1909: 37 (Hawaii). - Taylor 1964 (Nightcliff, Darwin).
Additional material from Leanyer Swamp.

Megalopidae

Megalops cyprinoides (Broussonet, 1782)

Clupea cyprinoides Broussonet, 1782: 39 (Tanna, New Hebrides).
Megalops cyprinoides - Paxton *et al.*1989 (NT).
Additional material from Coconut Grove and Leanyer Swamp.

Albulidae

Albula neoguinaica Valenciennes, 1847

Albula neoguinaica Valenciennes, 1847: 350 (New Guinea).
Albula vulpes neoguinaica - Whitley 1958 (Darwin).

ANGUILLIFORMES

Moringuidae

Moringua ferruginea Bliss, 1883

Moringua ferruginea Bliss, 1883: 57 (Mauritius). - Paxton *et al.*1989 (NT).
Aphthalmichthys intermedius Ogilby 1907: 9 (N coast of Australia, probably Darwin).

Uncertain record:
Moringua - Macleay 1878 (Port Darwin).

Muraenidae

Gymnothorax sp.

Specimens of an as yet unidentified species of this genus from Middle Arm and reef by East Arm boat ramp.

Siderea picta (Ahl, 1798)

Muraena picta Ahl, 1798: 6 (East Indies).
Lycodontis pictus - Martin 1978 (Darwin area).

Thrysoidea macrura (Bleeker, 1854)

Muraena macrurus Bleeker, 1854: 324 (Anjer).
Evenchelys macrurus - Whitley 1954 (Darwin).

Muraenosocidae

Muraenesox bagio (Hamilton, 1822)

Muraena bagio Hamilton, 1822: 24, 364 (Ganges River).

Muraenesox bagio - Paxton *et al.*1989 (NT).

Material from this species from Woods Inlet.

Ophichthidae

Muraenichthys sp.

Material as yet unidentified to species from the reef off Bullocky Point, the N side of Channel Island and East Arm.

? *Muraenichthys laticaudatus* (Ogilby, 1897)

Myropterura laticaudata Ogilby, 1897: 247 (Fiji).

One specimen from Woods Inlet, possibly of this species.

Pisodonophis cancrivorus (Richardson, 1848)

Ophisurus cancrivorus Richardson, 1848: 97 (Port Essington).

Myrophis chrysogaster Macleay, 1881: 271 (Port Darwin, NT).

Pisodonophis boro (Hamilton, 1822)

Ophisurus boro Hamilton 1822: 20, 363 (Ganges estuary near Calcutta).

Pisodonophis boro - Paxton *et al.*1989 (Darwin).

Pisodonophis sp.

?*Ophichthys* sp. - Macleay 1878 (Port Darwin).

Material of probably two as yet unidentified species from the N side of Channel Island, off Stokes Hill Wharf, East Arm, Woods Inlet and Rapid Creek.

CLUPEIFORMES

Clupeidae

Escualosa thoracata (Valenciennes, 1847)

Kowala thoracata Valenciennes, 1847: 363 (Pondicherry).

Harengula macrolepis - Taylor 1964 (Groote Eylandt).

Material from the reef by East Arm boat ramp.

Nematolosa come (Richardson, 1846)

Chateossus come Richardson 1846: 62 (Western Australia).

Chatoessus erebi - Saville-Kent 1889 (Port Darwin).

Additional specimens from the Buffalo Creek area.

Herklotsichthys gotoi Wongratana, 1983

Herklotsichthys gotoi Wongratana, 1983: 391 (Mimiko River, Papua New Guinea). - Paxton *et al.* 1989 (Darwin, NT).

An additional damaged specimen of what may be this species, from Darwin Harbour.

Sardinella albella (Valenciennes, 1847)

Kowala albella Valenciennes, 1847: 362 (Pondicherry).

Harengula bulan - Paradice and Whitley 1927 (Darwin).

Sardinella brachysoma Bleeker, 1852

Sardinella brachysoma Bleeker, 1852: 19 (Batavia).

Meletta schlegelii Castelnau, 1873: 93 (Port Darwin).

Sardinella gibbosa (Bleeker, 1849)

Clupea gibbosa Bleeker, 1849: 72 (Makassar).

Clupea tembang - Macleay 1878 (Port Darwin).

Engraulididae

Stolephorus sp.

Material of a unidentified species of the genus, from the reef by the East Arm Boat Ramp.

Thryssa hamiltoni (Gray, 1835)

Thrissa hamiltoni Gray, 1835: plate 2 (no locality).

Thrissocles hamiltoni - Paradice and Whitley 1927 (Darwin).

Additional specimens from Cullen Beach.

Thryssa setirostris (Broussonet, 1782)

Clupea setirostris Broussonet, 1782: text and plate 2, no pagination (Pacific Ocean near Tanna Is, Society Group).

Thryssa setirostris - Taylor 1964 (Nightcliff). Additional specimens from Cullen Beach.

Chirocentridae

Chirocentrus dorab (Forsskål, 1775)

Clupea dorab Forsskål 1775: 72 (Djedda and Mocha, Red Sea).

Chirocentrus dorab - Saville-Kent 1889 (Port Darwin); - Paxton *et al.*1989 (NT).

MYCTOPHIFORMES

Harpadontidae

Saurida micropectoralis
Shindo and Yamada, 1972

Saurida micropectoralis Shindo and Yamada, 1972: 11 (Gulf of Thailand). - Paxton *et al.* 1989 (Arafura Sea, NT).

Material from Station 30, this survey.

Saurida undosquamis (Richardson, 1848)

Saurus undosquamis Richardson, 1848: 138 (northwest of Australia).

Saurida undosquamis - Whitley 1954 (Charles Point).

Additional material from off Charles Point.

Synodontidae

Synodus sageneus Waite, 1905

Synodus sageneus Waite, 1905: 58 (Fremantle). - Paxton *et al.*1989 (NT).

Material from Vesteys Beach.

GONORHYNCHIFORMES

Chanidae

Chanos chanos (Forsskål, 1775)

Mugil chanos Forsskål, 1775: 74 (Jedda, Red Sea).

Chanos chanos - Paxton *et al.*1989 (NT).

Material from the creek at Mindil Beach and Leanyer Swamp.

SILURIFORMES

Ariidae

Arius argyropleuron Valenciennes, 1840

Arius argyropleuron Valenciennes, 1840: 104 (Java).

Hemipimelodus colcloughi Ogilby, 1910: 7 (Crocker [= Croker] Island, NT).

Material from Woods Inlet.

Arius armiger De Vis, 1884

Arius armiger De Vis, 1884: 454 (locality uncertain).

Arius stirlingi Ogilby, 1910: 281 (Adelaide River, NT).

Small specimens, probably of this species, from Cullen Beach.

Arius graeffei Kner and Steindachner, 1866

Arius graeffei Kner and Steindachner, 1866: 383 (type locality uncertain). - Kailola 1983 (Jabiru and Long Harry's Billabong, Daly River, NT).

Additional material from Ludmilla Creek and Woods Inlet.

Arius mastersi Ogilby, 1898

Arius gagorides - Macleay 1881 (Port Darwin).

Arius mastersi Ogilby, 1898: 34 (Port Darwin).

Macleay's Port Darwin specimen, identified as *Arius gagorides*, became the holotype of *Arius mastersi* Ogilby 1898. Additional material from Ludmilla Creek and Vesteys Beach boat ramp.

Arius proximus Ogilby, 1898

Arius proximus Ogilby, 1898: 280 (Port Darwin).

Additional material from East Point and Elizabeth River mouth.

Arius sp. 3

Material from Ludmilla Creek. This is a new species presently being described by P. Kailola.

Arius sp. 4

Material from Ludmilla Creek. This is a new species presently being described by P. Kailola.

Arius thalassinus (Rüppell, 1835)

Bagrus thalassinus Rüppell, 1837: 75 (Massaua, Red Sea).

Arius thalassinus - Macleay 1878 (Port Darwin).

Plotosidae

Euristhmus lepturus (Günther, 1864)

Cnidoglanis lepturus Günther, 1864: 28 (Sydney).

?*Cnidoglanis megastoma* - Macleay 1878 (Port Darwin).

Additional material from Woods Inlet.

Paraplotosus albilabrus (Valenciennes, 1840)

Plotosus albilabrus Valenciennes, 1840: 427 (Batavia). - Whitley 1940 (Port Darwin).
Cnidoglanis mulleri Klunzinger, 1879: 411 (Port Darwin).
Additional material from East Point Reef, Lee Point shore reef and Channel Island.

Plotosus lineatus (Thunberg, 1791)

Silurus lineatus Thunberg, 1791: 190 (Indian Ocean).
Plotosus anguillaris - Macleay 1878 (Port Darwin).
Additional material from Cullen Beach.

BATRACHOIDIFORMES

Batrachoididae

Batrachomoeus trispinosus (Günther, 1861)

Batrachus trispinosus Günther, 1861: 169 (Singapore and Penang).
Batrachomoeus trispinosus - Hutchins 1976 (Darwin).
Additional material from E of South Shell Island, the bottom end of Woods Inlet and the East Arm mudflats.

Halophryne diemensis (Le Sueur, 1824)

Batrachoides diemensis Le Sueur, 1824: 402 (coasts of Van Diemen's Land).
Batrachus mulleri Klunzinger, 1879: 387 (Port Darwin).
Additional material from East Point shore reef, Lee Point shore reef and Nightcliff shore reef.

LOPHIIFORMES

Antennariidae

Antennarius commersoni (Latreille, 1804)

Lophius commerson Latreille, 1804: 387 (no known type material).
Antennarius commersonii - Macleay 1878: (Port Darwin).

Lophiocharon trisignatus (Richardson, 1844)

Cheironectes trisignatus Richardson, 1844 (King George's Sound, WA).
Antennarius urophthalmus - Macleay 1878 (Port Darwin).
Antennarius (Plumantennatus) asper - Schultz 1957 (Woods Inlet, West of Darwin).
Additional material from the Navy Landing, Vesteys Beach reef and Channel Island.

Tathicarpus butleri Ogilby, 1907

Tathicarpus butleri Ogilby, 1907: 20 (Port Curtis, Queensland). - Schultz 1957 (Jarape, north coast of Groote Eylandt).
Material from Darwin Harbour.

GADIFORMES

Bregmacerotidae

Bregmaceros mcclellandi Thompson, 1840

Bregmaceros mcclellandi Thompson, 1840 (Ganges Delta). - McCulloch 1926 (Darwin).

Bregmaceros nectabanus Whitley, 1941

Bregmaceros nectabanus Whitley, 1941: 25 (Darwin).

Bythitidae

Dinematichthys sp.

Material of an as yet unidentified species of this genus from Channel Island, Weed Reef and the East Arm Boat Ramp reef.

Monothrix mizolepis (Günther, 1867)

Dinematichthys mizolepis Günther, 1867: 66 (Cape York, Queensland). - Paxton *et al.*1989 (Darwin).

Carapidae

Onuxodon sp.?

Fierasfer sp. - Saville-Kent 1889 (Port Darwin).
Saville-Kent's record was likely to be that of a species of *Onuxodon*, a genus which occurs offshore in the NT.

ATHERINIFORMES

Hemiramphidae

Arrhamphus sclerolepis Günther, 1866

Arrhamphus sclerolepis Günther, 1866: 277 (New Zealand; =Australia). - Macleay 1878 (Darwin).
Additional material from NW side Channel Island.

Hemiramphus far (Forsskål, 1775)

Esox far Forsskål, 1775: 67 (Jidda, Red Sea).
Hemirhamphus far - Paradice and Whitley 1927 (Darwin and Pellew Islands).

Hyporhamphus neglectissimus Parin, Collette and Shcherbachev, 1980

Hyporhamphus neglectissimus Parin, Collette and Shcherbachev, 1980: 34 (New Guinea).

Hyporhamphus gaimardi - Taylor 1964 (Nightcliff, Arnhem Land).

Hyporhamphus quoyi (Valenciennes, 1847)

Hemiramphus quoyi Valenciennes, 1847 (Port Dourey, Papua).

Belone quoyi - Klunzinger 1879 (Port Darwin).

Zenarchopterus buffonis (Valenciennes, 1847)

Hemiramphus buffonis Valenciennes, 1847: 48-49 (Pulo Pinan).

Zenarchopterus buffonis - Taylor 1964 (Nightcliff, Wood's Inlet, Port Bradshaw).

Additional material from East Point, NW side Channel Island and East Arm.

Zenarchopterus caudovittatus Weber, 1908

Hemiramphus (Zenarchopterus) caudovittatus Weber, 1908: 1 (Merauke River, New Guinea).

Hemiramphus amblyurus - Macleay 1878 (Port Darwin).

Zenarchopterus dispar (Valenciennes, 1847)

Hemiramphus dispar Valenciennes, 1847: 58-62 ("Madagascar?").

Zenarchopterus dispar - Collette 1974 (Blackmore River, south end of Darwin Harbour).

Zenarchopterus gilli Smith, 1945

Zenarchopterus gilli Smith, 1945: 432 (*nom. nov.* for *Hemirhamphus brevirostris* Günther, 1866; East Indies). - Taylor 1964 (East Point Reef, Groote Eylandt, Port Bradshaw).

Zenarchopterus rasori (Popta, 1912)

Hemiramphus rasori Popta, 1912: 192-193 (Muna Is, Celebes).

Zenarchopterus rasori - Taylor 1964 (Wood's Inlet, Delissaville, NT).

Additional material from East Arm and Woods Inlet.

Belonidae

Strongylura leiura (Bleeker, 1851)

Belone leiurus Bleeker, 1851: 94 (Java).

Strongylura leiura - Paxton *et al.*1989 (NT).

Additional material from Fannie Bay, by Museum.

Strongylura strongylura (van Hasselt, 1823)

Belone strongylura van Hasselt, 1823: 130 (Vizagapatam, India).

Strongylura strongylura - Paxton *et al.*1989 (NT).

Additonal material from Ludmilla Creek, NW side Channel Island and Cullen Beach.

Tylosurus acus (Lacepède, 1803)

Sphyraena acus Lacepède, 1803 (Martinique, West Indies).

Belone melanotus - Macleay 1878 (Port Darwin).

Tylosurus acus - Paxton *et al.*1989 (off Darwin, NT).

Tylosurus gavialoides (Castelnau, 1873)

Belone gavialoides Castelnau, 1873: 142 (Fremantle).

Belone groeneri Klunzinger, 1880: 414 (Port Darwin, NT).

Melanotaeniidae

Pseudomugil cyanodorsalis Allen and Sarti, 1983

Pseudomugil cyanodorsalis Allen and Sarti, 1983: 48 (Broome, WA; paratypes from Channel Island, Elizabeth River, NT).

Additional material from Ludmilla Creek, S end of Channel Island and creek at Elizabeth River mouth.

Pseudomugil inconspicuus Roberts, 1978

Pseudomugil inconspicuus Roberts, 1978: 53 (tributary of the Fly River, Papua New Guinea). - Saeed, Ivantsoff and Allen 1989 (mangrove swamps around Darwin).

Additonal material from Woods Inlet.

Atherinidae

Atherinomorus endrachtensis (Quoy and Gaimard, 1825)

Atherina endrachtensis Quoy and Gaimard, 1825: 334 (Shark's Bay, Endracht's Land, WA).
Pranesus endrachtensis - Taylor 1964 (Nightcliff).
Additional material from East Arm boat ramp reef and Channel Island.

Atherinomorus lacunosus (Forster, 1801)

Atherina lacunosa Forster, 1801: 112 (New Guinea).
Atherinomorus lacunosus - Paxton *et al.*1989 (Darwin, NT).

Craterocephalus capreoli Rendahl, 1922

Craterocephalus capreoli Rendahl, 1922: 175 (Roebuck Bay,WA).
Craterocephalus pauciradiatus - Taylor 1964 (Nightcliff).

Craterocephalus mugiloides (McCulloch, 1912)

Atherina mugiloides McCulloch, 1913: 47 (new name for *Atherinichthys punctatus* De Vis 1885, preoccupied; Cape York).
Allanetta mugiloides - Taylor 1964 (Nightcliff).
Additional material from Lee Point and reef by East Arm boat ramp.

BERYCIFORMES

Holocentridae

Sargocentron rubrum (Forsskål, 1775)

Sciaena rubra Forsskål, 1775: 48 (Red Sea).
Holocentrum rubrum - Macleay 1878 (Port Darwin).
Additional material from East Point Reef.

SYNGATHIFORMES

Centriscidae

Centriscus scutatus Linnaeus, 1758

Centriscus scutatus Linnaeus, 1758: 336 (eastern India). - Paxton *et al.*1989 (NT).
Material from Darwin Harbour: Francis Bay, Fannie Bay.

Syngnathidae

Campichthys tricarinatus Dawson, 1977

Campichthys tricarinatus Dawson, 1977: 641 (Baleine Bank, WA).
Campichthys tricarinatus - Dawson 1985 (New Year Island, NT).
Material from Channel Island.

Choeroichthys brachysoma (Bleeker, 1855)

Syngnathus brachysoma Bleeker, 1851: 327 (Batu Archipelago).
Choeroichthys serialis - Whitley 1954 (Port Darwin).
Additional material from Lee Point Reef, reef off Bullocky Point and N side Channel Island.

Corythoichthys haematopterus (Bleeker, 1851)

Syngnathus haematopterus Bleeker, 1851: 258 (Banda Neira)
Corythoichthys haematopterus - Paxton *et al.*1989 (Darwin, NT).

Festucalex cinctus (Ramsay, 1882)

Syngnathus cinctus Ramsay, 1882: 111 (Port Jackson, NSW).
Festucalex cinctus - Paxton *et al.*1989 (Arnhem Land, NT).
Material from bottom end Woods Inlet.

Halicampus brocki (Herald, 1953)

Micrognathus brocki Herald, 1953: 263 (Amen I., Bikini Atoll, Marshall Is.) - Dawson 1985 (spot on map only: Darwin).).
Halicampus brocki - Paxton *et al.*1989 (Darwin, NT).

Halicampus dunckeri (Chabanaud, 1929)

Micrognathus dunckeri Chabanaud, 1929: 170 (Amboina).
Halicampus dunckeri - Paxton *et al.*1989 (Darwin, NT).

Halicampus grayi Kaup, 1853

Halicampus conspicillum Kaup 1856: 22 (*nomen nudum*, = *Halicampus grayi* Kaup 1856; India, New Holland).
Halicampus grayi - Dawson 1985 (spot on map only: Darwin).

Haliichthys taeniophora Gray, 1859

Haliichthys taeniophora Gray, 1859: 39 (Freycinet's Harbour, Shark Bay, WA). - Paxton *et al.*1989 (NT).

Additional material from Fannie Bay and East Point Reef.

Hippichthys cyanospilus (Bleeker, 1854)

Syngnathus cyanospilus Bleeker, 1854: 114 (Banda Neira).

Hippichthys cyanospilus - Paxton *et al.*1989 (Croker Island, NT).

Additional material from reef off Bullocky Point and East Arm.

Hippichthys parvicarinatus Dawson, 1978

Syngnathus parvicarinatus Dawson, 1978: 288 (Dinah Beach Inlet, Darwin, NT).

Additional material from Ludmilla Creek.

Hippichthys penicillus (Cantor, 1850)

Syngnathus penicillus Cantor, 1850: 1849 (Sea of Pinang, Malaysia).

Hippichthys penicillus - Paxton *et al.*1989 (NT).

Additional material from Ludmilla Creek, NW side of Channel Island, and Woods Inlet.

Hippocampus histrix Kaup, 1856

Hippocampus histrix Kaup, 1856: 17 (Japan).

Material from the bottom end of Woods Inlet. A new record for the Northern Territory.

Hippocampus kuda Bleeker, 1852

Hippocampus kuda Bleeker, 1852: 82 (Singapore). - Paxton *et al.*1989 (Port Darwin, NT).

Additional material from Darwin Harbour.

Hippocampus planifrons Peters, 1877

Hippocampus planifrons Peters, 1877: 851 ("Naturalist's Channel", NW Australia).

Material from off Cullen Beach. A new record for the Northern Territory.

Hippocampus trimaculatus Leach, 1814

Hippocampus trimaculatus Leach, 1814: 104 (Indian and Chinese Seas).

Material from Fannie Bay. A new record for the Northern Territory.

Micrognathus micronotopterus (Fowler, 1938)

Syngnathus micronotopterus Fowler, 1938: 42 (in part; Canimo Island, Philippines).

Micrognathus brevirostris - Taylor 1964 (Yirrkala, NT).

Material from off East Point.

Trachyrhamphus bicoarctatus (Bleeker, 1857)

Syngnathus bicoarctatus Bleeker, 1857: 99 (Ambon).

Ichthyocampus annulatus Macleay, 1878: 364 (Port Darwin, NT).

Trachyrhamphus longirostris Kaup, 1856

Trachyrhamphus longirostris Kaup, 1856: 24 (Asia). - Paxton *et al.*1989 (NT).

Material from mid-channel, Woods Inlet.

Dubious record:

Stigmatophora argus - Klunzinger 1879 (Port Darwin, Port Philip). Klunzinger apparently mixed up material from both localities; *Stigmatophora* is a temperate genus.

SYNBRANCHIFORMES

Synbranchidae

Ophisternon gutturale (Richardson, 1845)

Synbranchus gutturalis Richardson, 1845: 49 (Dampier Archipelago, WA). - Macleay 1881 (Port Darwin).

SCORPAENIFORMES

Scorpaenidae

Liocranium praepositum Ogilby, 1903

Liocranium praepositum Ogilby, 1903: 25 (coast of Queensland).

Abcichthys praepositum - Whitley 1954 (Port Darwin).

Additional material from Fannie Bay.

Dendrochirus zebra (Cuvier, 1829)

Pterois zebra Cuvier, 1829: 367 (Amboina, Mauritius, New Guinea).

Dendrochirus zebra - Martin 1978 (Darwin area).

Paracentropogon sp.

Material of an as yet unidentified species from Station 69, this survey.

Pterois volitans (Linnaeus, 1758)

Gasterosteus volitans Linnaeus, 1758: 296 (Amboina).

Pterois volitans - Saville-Kent 1889 (Port Darwin).

Scorpaena picta Kuhl and van Hasselt, 1829

Scorpaena picta Kuhl and van Hasselt, 1829: 321 (Java).

Sebastapistes bynoensis Macleay 1878 (Port Darwin).

Material from the reef off Bullocky Point, and off NW tip of East Point.

Scorpaenopsis diabolus Cuvier, 1829

Scorpaenopsis diabolus Cuvier, 1829: 312 ("le grande Ocean orientale"). - Paxton *et al.* 1989 (NT).

Scorpaena diabolus - Macleay 1878 (Port Darwin).

Synanceia horrida (Linnaeus, 1766)

Scorpaena horrida Linnaeus, 1766: 453 (East Indies).

Synanceia trachynis Richardson, 1842: 385 (Port Essington).

Synancidium horridum - Klunzinger 1879 (Port Darwin).

Additional material from Ludmilla Creek and off Stokes Hill Wharf.

Dubious record:

Pentaroge marmorata - Klunzinger 1879 (Port Darwin).

Klunzinger's record of this species was based upon specimens from "Port Darwin, King George's Sound and Port Philipp"; the species is restricted to southern Australia from Fremantle to Sydney.

Aploactinidae

Paraploactis trachyderma Bleeker, 1865

Paraploactis trachyderma Bleeker, 1865: 169 (Australia).

One specimen from Station 182, this survey. A new record for the Northern Territory.

Platycephalidae

Inegocia harrisii

Insidiator harrisii McCulloch 1914: 146 (off Pine Peak, and Moreton Bay). - Sainsbury *et.al.* 1985: 336 (Arafura Sea, NT).

Material from the Harbour, this survey.

Inegocia japonica (Tilesius, 1812)

Platycephalus japonicus Tilesius, 1812: 1814 (Nagasaki).

Platycephalus isacanthus - Macleay 1880 (Port Darwin).

Inegocia japonica - Paxton *et al.*1989 (NT).

Material from S of Dudley Point and Woods Inlet.

Papilloculiceps nematophthalmus (Günther, 1860)

Platycephalus nematophthalmus Günther, 1860: 184 (Victoria, Port Essington).

Cymbacephalus nematophthalmus - Paxton *et al.*1989 (NT).

Material from Ludmilla Creek, N side Channel Island and East Arm.

Platycephalus endrachtensis Quoy and Gaimard, 1825

Platycephalus endrachtensis Quoy and Gaimard, 1825: 466 (Great Australian Bight). - Paxton *et al.*1989 (NT).

Material from Woods Inlet.

Platycephalus indicus (Linnaeus, 1758)

Callionymus indicus Linnaeus, 1758: 250 (Asia).

Platycephalus indicus - Paxton *et al.*1989 (NT).

Material from Ludmilla Creek, East Arm and Woods Inlet.

Leviprora inops (Jenyns, 1840)

Platycephalus inops Jenyns, 1840: 33 (King George's Sound, WA). - Macleay 1878 (Port Darwin).

Knapp (in MS) says that Macleay's record is dubious; Paxton *et al.*'s (1989) NT record is based on Macleay.

Suggrundus bosschei (Bleeker, 1860)

Platycephalus bosschei Bleeker, 1860: 140 (Muntok, Banka).
Insidiator bosschei - McCulloch 1914 (Port Darwin).
Additional material from Vesteys Beach.

Suggrundus staigeri (Castelnau, 1875)

Platycephalus staigeri Castelnau, 1875: 17 (Queensland).
Isidiator parilis McCulloch, 1914: 151 (Port Darwin, NT).
Paxton *et al.* (1989) tentatively place this under *staigeri*, and say that *parilis* may be a valid species (NT).
Additional material from Fannie Bay and off Dudley Point.

PEGASIFORMES

Pegasidae

Pegasus volitans Linnaeus, 1758

Pegasus volitans Linnaeus, 1758: 338 (Amboina). - Whitley and Allan 1958 (NT).
Material from W of Nightcliff boat ramp and the bottom end Woods Inlet.

PERCIFORMES

Centropomidae

Lates calcarifer (Bloch, 1790)

Holocentrus calcarifer Bloch, 1790: 100 (Japan).
Lates darwinensis Macleay,1878: 345 (Port Darwin, NT).
Additional material from mouth of Elizabeth River, N side of Channel Island, and Woods Inlet.

Psammoperca waigiensis (Cuvier, 1828)

Labrax waigiensis Cuvier, 1828: 83 (Waigiou).
Psammoperca waigiensis - Paxton *et al.* 1989 (NT).
Material from E of South Shell Island.

Ambassidae

Ambassis gymnocephalus (Lacepède, 1802)

Lutjanus gymnocephalus Lacepède, 1802: 181, 216 (Indo-Pacific Ocean).
Ambassis (Priopis) gymnocephalus - Paradice and Whitley 1927 (Darwin).
Additional material from Leanyer Swamp bomb craters.

Ambassis interruptus Bleeker, 1852

Ambassis interruptus Bleeker, 1852: 696 (Celebes).
Ambassis dalyensis Rendahl, 1922: 187 (Daly River, NT).
Material from Woods Inlet.

Ambassis nalua (Hamilton, 1822)

Chanda nalua Hamilton Buchanan, 1822: 107 (Ganges).
Ambassis nalua - Paradice and Whitley 1927 (Darwin).
Additional material from N side Channel Island and East Arm.

Ambassis vachelli Richardson, 1846

Ambassis vachelli Richardson, 1846: 221 (Canton).
Ambassis dussumieri - Klunzinger 1879 (Port Darwin).
Additional material from Ludmilla Creek and East Arm Boat Ramp.

Serranidae

Centrogenys vaigiensis (Quoy and Gaimard, 1824)

Scorpaena vaigiensis Quoy and Gaimard, 1824: 324 (Waigou).
Centropristes scorpaenoides - Richardson 1842 (Port Essington).
Myriodon waigiensis - Macleay 1878 (Port Darwin).
Additional material from off Dudley Point and reef off Bullocky Point.

Cephalopholis boenak (Bloch, 1790)

Bodianus boenak Bloch, 1790: 43 (Japan).
Serranus pachycentrum - Macleay 1878 (Port Darwin).
Serranus boenack - Klunzinger 1879 (Port Darwin).
Additional material from off NW tip East Point and Channel Island.

Cromileptes altivelis (Valenciennes, 1828)

Serranus altivelis Valenciennes, 1828: 324 (Java).
Chromileptes altivelis - Paxton *et al.*1989 (NT).
Material from Elizabeth River.

Epinephelus coioides (Hamilton, 1822)

Bola? coioides Hamilton, 1822: 82 (Ganges estuaries).

Serranus pantherinus - Klunzinger 1879 (Port Darwin).

? *Serranus merra* - Macleay 1878 (Port Darwin).

Epinephelus suillus - Paxton *et al.*1989 (NT).

Epinephleus coioides - Randall and Heemstra 1991 (Lee Point).

Additional material from Nightcliff, reef off Bullocky Point and N side Channel Island.

Epinephelus corallicola (Valenciennes, 1828)

Serranus corallicola Valenciennes, 1828: 336 (Java). - Macleay 1878 (Port Darwin).

Epinephelus corallicola - Randall and Heemstra 1991 (Darwin, Lee Point).

Epinephelus fuscoguttatus (Forsskål, 1775)

Perca summana var. fusco-guttatus Forsskål, 1775: 41 (Suerens and Djeddah).

Serranus fuscoguttatus - Günther 1859 (Port Darwin).

Epinephelus lanceolatus (Bloch, 1790)

Holocentrus lanceolatus Bloch, 1790: 92 (East Indies).

Epinephelus lanceolatus - Taylor 1964 (Groote Eylandt).

Material from Elizabeth River and Mandorah Wharf.

Epinephelus malabaricus (Bloch and Schneider, 1801)

Holocentrus malabaricus Bloch and Schneider, 1801: 319 (Tranquebar, India).

Serranus crapao - Macleay 1878 (Port Darwin).

Epinephelus malabaricus - Paxton *et al.*1989 (NT).

Macleay's record is likely to be of an *E. coioides*; the two species are known to occur in the harbour.

Epinephelus quoyanus (Valenciennes, 1830)

Serranus quoyanus Valenciennes, 1830: 519 (New Guinea).

? *Serranus hexagonatus* - Klunzinger 1879 (Port Darwin).

Epinephelus megachir - Paradice and Whitley 1927 (Darwin).

Additional material from off NW tip East Point and reef off Bullocky Point.

Epinephelus sexfasciatus Valenciennes, 1828

Serranus sexfasciatus Valenciennes, 1828: 360 Java.

Epinephelus sexfasciatus - Paxton *et al.*1989 (NT); - Randall and Heemstra 1991 (Darwin).

Diploprion bifasciatum Kuhl and van Hasselt, 1828

Diploprion bifasciatum Kuhl and van Hasselt, 1828: 137 (Java). - Macleay 1878 (Port Darwin).

Additional material from Darwin Harbour.

Plectropomus maculatus (Bloch, 1790)

Bodianus maculatus Bloch, 1790: 48 (Japan; probably error for Java).

Plectropomus maculatus - Paradice and Whitley 1927 (Pellew Islands).

Material from Darwin Harbour and Lee Point Reef.

Pseudochromidae

Assiculus punctatus Richardson, 1846

Assiculus punctatus Richardson, 1846: 494 (NW Australia).

Pseudochromis mulleri Klunzinger, 1890: 370 (Port Darwin, NT).

Cichlops filamentosus Macleay, 1881: 570 (Port Darwin, NT).

Additional material from off East Point, reef off Bullocky Point and Middle Arm.

Congrogadus spinifer (Borodin, 1933)

Congrogadoides spinifer Borodin, 1933: 141 (Broome, WA). - Whitley 1964 (Darwin).

Additional material from Channel Island and off NW tip East Point.

Congrogadus subducens (Richardson, 1843)

Machaerium subducens Richardson, 1843: 175 (bays of Port Essington).

Congrogadus subducens - Macleay 1878 (Port Darwin).

Additional material from reef off Bullocky Point, Channel Island, Vesteys Beach and East Arm boat ramp reef.

Pseudochromis wilsoni (Whitley, 1929)

Leptochromis tapeinsoma wilsoni Whitley, 1929: 113 (Port Darwin, NT).
Additional material from Nightcliff shore reef, off NW tip East Point and Channel Island.

Teraponidae

Amniataba caudavittata (Richardson, 1845)

Datnia caudavittata Richardson, 1845: 24 (Harvey River, WA).
Therapon caudavittatus - Macleay 1878 (Port Darwin).
Additional material from Cullen Beach and Ludmilla Creek.

Pelates quadrilineatus (Bloch, 1790)

Holocentrus quadrilineatus Bloch,1790: 82 ("The Orient").
? *Helotes sexlineatus* - Macleay 1878 (Port Darwin).
Therapon cuvieri - Macleay 1878 (Port Darwin).
Additional material from reef by East Arm ramp.

Terapon jarbua (Forsskål, 1775)

Sciaena jarbua Forsskål, 1775: 12 (Djeddah, Red Sea).
Therapon servus - Richardson 1842 (Port Essington).
Therapon jarbua - Klunzinger 1879 (Port Darwin).
Additional material from Vesteys Beach and Cullen Beach.

Terapon puta (Cuvier, 1829)

Therapon puta Cuvier, 1829: 131 (Pondicherry, Vizagapatam).
Terapon puta - Paradice and Whitley 1927 (Pellew Islands).
Material from three stations, this survey.

Terapon theraps Cuvier, 1829

Therapon theraps Cuvier, 1829: 129 (Indian Seas).
Therapon theraps - Richardson 1842 (Port Essington).
Material from off East Point.

Apogonidae

Apogon albimaculosus Kailola,1976

Apogon albimaculosus Kailola, 1976: 129 (between Gloucester Island and Bowen, Queensland). - Paxton *et al.*1989 (vicinity of Darwin, NT).
Additional material from Station 69, this survey.

Apogon brevicaudata Weber, 1909

Apogon brevicaudata Weber, 1909: 158 (Aru Islands). - Paxton *et al.*1989 (NT).
Material from N of East Point.

Apogon cooki Macleay, 1881

Apogon cooki Macleay, 1881: 344 (Endeavour River and Darnley Island, Queensland).
Lovamia cooki - Munro 1958 (NT).
Material from Casuarina Beach, off NW tip East Point and off Dudley Point.

Apogon ellioti Day, 1875

Apogon ellioti Day, 1875: 63 (Bay of Bengal). - Paxton *et al.*1989 (NT).
Apogonichthys australis - Munro 1958 (Darwin).

Apogon fasciatus (White, 1790)

Mullus fasciatus White, 1790: 268 (NSW).
Apogon fasciatus - Klunzinger 1879 (Port Darwin).
Material from five stations, this survey.

Apogon fraenatus Valenciennes, 1832

Apogon fraenatus Valenciennes, 1832: 57 (New Guinea and Guam).
Pristiapogon fraenatus - Munro 1958 (Darwin).

Apogon hyalosoma Bleeker, 1852

Apogon hyalosoma Bleeker, 1852: 63 (Java, Sumatra, Sumbawa). - Macleay 1878 (Port Darwin).

Apogon melanopus Weber, 1911

Apogon melanopus Weber, 1911: 28 (Aru Islands).
Apogon fusovatus Allen, 1985: 11 (vicinity of Darwin, NT).
Additional material from six stations, this survey.

Apogon opercularis Macleay, 1878

Apogon opercularis Macleay, 1878: 347 (Port Darwin, NT).

Additional material from East Point and reef off Bullocky Point.

Apogon poecilopterus Cuvier, 1828

Apogon poecilopterus Cuvier, 1828: 154 (Java). - Russell and Houston 1989 (Arafura Sea, NT).

Material from Station 181, this survey.

Apogon rueppellii Günther, 1859

Apogon rueppellii Günther, 1859: 236 (Victoria, Port Essington, NT). - Paxton *et al.*1989 (Darwin, NT).

Additional material from reef off Bullocky Point, East Arm and bottom end Woods Inlet

Apogon timorensis Bleeker, 1854

Apogon timorensis Bleeker, 1854: 207 (Timor). - Paxton *et al.*1989 (NT).

Material from reef by East Arm boat ramp.

Apogon unitaeniatus Allen, 1995

Apogon unitaeniatus Allen, 1995: 177 (off NE portion of Bonaparte Achipelago, Western Australia [paratypes from Northern Territory]).

Six lots of paratypes from this survey.

Apogonichthys sp.

An unidentified specimen of this genus from Darwin Harbour.

Archamia melasma Lachner and Taylor, 1960

Archamia melasma Lachner and Taylor, 1960: 29 (Yirrkala, NT).

Material from Darwin.

Fowleria aurita (Valenciennes, 1831)

Apogon auritus Valenciennes, 1831: 443 (Mauritius). - Klunzinger 1879 (Port Darwin).

Additional material from Lee Point Reef.

Fowleria punctulata (Rüppell, 1838)

Apogon punctulatus Rüppell, 1838: 88 (Massaua, Red Sea). - Paxton *et al.* 1989 (NT).

Material from Channel Island and Vesteys Beach.

Gymnapogon sp.

Material of an as yet unidentified species of this genus from off East Point and from East Arm.

Gymnapogon annona (Whitley, 1936)?

Australaphia annona Whitley, 1936: 49 (Lindeman Island, Queensland).

Material from reef by East Arm boat ramp. New record for the Northern Territory.

Pseudamia nigra Allen, 1992

? *Apogonichthys polystigma* - Macleay 1878 (Port Darwin)

Pseudamia nigra Allen, 1992: 697-698 (King George River, WA).

Paratypes from other localities including Pearl Raft Creek, East Arm Darwin Harbour and Woods Inlet.

Siphamia roseigaster (Ogilby, 1886)

Apogon roseigaster Ogilby, 1886: 8 (Parramatta River, NSW).

Material from four stations, this survey. A new record from the Northern Territory. This species is noted by Paxton *et al.* (1988) as being a temperate endemic. Specimens from the Northern Territory and northern Western Australia agree in fin ray counts with Ogilby's original description.

Sillaginidae

Sillago analis Whitley, 1943

Sillago analis Whitley, 1943: 184 (Shark Bay, WA).

Sillago ciliata - Paradice and Whitley 1927 (Pellew Islands).

Material from Fannie Bay.

Sillago maculata burrus Richardson, 1842

Sillago burrus Richardson, 1842: 128 (Northwest Australia).

Sillago gracilis - Saville-Kent 1889 (Port Darwin).

Additional material from Ludmilla Creek.

Sillago lutea McKay, 1985

Sillago sp. 4 - Gloerfelt-Tarp and Kailola 1984 (Darwin).

Sillago (Parasillago) lutea McKay, 1985: 41 (Exmouth Gulf, WA; paratypes from Darwin).

Additional material from Fannie Bay.

Sillago sihama (Forsskål, 1775)

Atherina sihama Forsskål, 1775: 70 (Lohaja, Red Sea).
Sillago sihama - Paradice and Whitley 1927 (Darwin).
Additional material from Buffalo Creek area and Cullen Beach.

Rachycentridae

Rachycentron canadum (Linnaeus, 1766)

Gasterosteus canadus Linnaeus, 1766: 491 (Carolina, USA).
Rachycentron canadus - Stevens, Davis and Church 1982 (E of Melville Island, NT).
Material from Darwin Harbour.

Echeneididae

Echeneis naucrates Linnaeus, 1758

Echeneis naucrates Linnaeus, 1758: 261 (Indian Ocean). - Richardson 1843 (Port Essington).
Material from the mouth of Buffalo Creek.

Carangidae

Alectis indicus (Rüppell, 1830)

Scyris indicus Rüppell, 1830: 128 (Djedda, Red Sea).
Alectis indica - Paradice and Whitley 1927 (Pellew Islands).
Material from Cullen Beach.

? *Alepes vari* (Cuvier, 1833)

Caranx vari Cuvier, 1833: 48 (Pondicherry).
? *Alepes* sp. - Gunn 1990 (NT).
Material from Buffalo Creek. This genus is under revision.

Carangoides hedlandensis (Whitley, 1934)

Olistus hedlandensis Whitley, 1934: 156 (Port Hedland, WA).
? *Caranx armatus* - Paradice and Whitley 1927 (Pellew Islands).
Carangoides hedlandensis - Paxton *et al.*1989 (NT).
Material from SW of South Shell Island.

Caranx bucculentus Alleyne and Macleay, 1877

Caranx bucculentus Alleyne and Macleay, 1877: 326 (Cape Grenville, Queensland). - Paradice and Whitley 1927 (Pellew Islands).
Material from Station 184, this survey.

Caranx ignobilis (Forsskål, 1775)

Scomber ignobilis Forsskål, 1775: 55 (Red Sea).
Caranx ignobilis - Klunzinger 1879 (Port Darwin).
Additonal material from Cullen Beach and NW side Channel Island.

Pantolabus radiatus (Macleay, 1881)

Caranx radiatus Macleay, 1881: 537 (Rockingham Bay, Queensland). - Paradice and Whitley 1927 (Pellew Islands)
Material from Woods Inlet mouth and Fannie Bay.

Scomberoides commersonianus Lacepède, 1801

Scomberoides commersonianus Lacepède, 1801: 50 (Madagascar). - Smith-Vaniz and Staiger 1973 (Charles Point, NT).
Scomberoides lysan - Günther 1860 (Port Essington).
Additional material from Cullen Beach, Buffalo Creek area and Fannie Bay rocks.

Scomberoides lysan (Forsskål, 1775)

Scomber lysan Forsskål, 1775: 54 (Red Sea).
Scomberoides toolooparah - Whitley 1951 (Darwin).

Scomberoides tala (Cuvier, 1832)

Chorinemus tala Cuvier, 1832: 377 (Malabar).
Scomberoides tala - Taylor 1964 (Groote Eylandt).
Material from Cullen Beach.

Trachinotus anak Ogilby, 1909

Trachinotus anak Ogilby, 1909: 19 (Wide Bay district, Queensland). - Paxton *et al.*1989 (Darwin, NT).
Additional material from Channel Island area and Woods Inlet.

Leiognathidae

Leiognathus sp.

Leiognathus sp. - Jones 1985 (Arafura Sea). - Russell and Houston 1989 (Arafura Sea, NT).
Material from stations 30 and 33, this survey.

Leiognathus bindus (Valenciennes, 1835)

Equula bindus Valenciennes, 1835: 78 (based on figure).

Leiognathus bindus - Jones 1985 (Arafura Sea, Melville Bay, NT).

Material from East Arm Boat ramp reef.

Leiognathus decorus (de Vis, 1884)

Equula decora de Vis, 1884: 543 (Cape York). - Jones 1985: (Darwin, NT).

Additional material from Buffalo Creek area and Cullen Beach.

Leiognathus equula (Forsskål, 1775)

Scomber equula Forsskål, 1775: 75 (Red Sea).

Equula edentula - Castelnau 1873 (Port Darwin).

Material from creek at Mindil Beach.

Leiognathus fasciatus (Lacepède, 1801)

Clupea fasciata Lacepède, 1801: 460 (Mauritius).

Leiognathus fasciatus - Jones 1985 (Darwin, NT).

Leiognathus moretoniensis Ogilby, 1912

Leiognathus moretoniensis Ogilby, 1912: 59 (Moreton Bay, Queensland). - Paradice and Whitley 1927 (Pellew Islands).

Material from station 60, this survey.

Leiognathus splendens (Cuvier, 1829)

Equula splendens Cuvier, 1829: 212 (described from figure).

Leiognathus splendens - Paradice and Whitley 1927 (Pellew Islands).

Material from Cullen Beach.

Secutor insidiator (Bloch, 1787)

Zeus insidiator Bloch, 1787: 41 (Suratte, India)

Secutor insidiator - Jones 1985 (Arafura Sea, NT).

Material from Woods Inlet mouth.

Secutor ruconius (Hamilton, 1822)

Chanda ruconius Hamilton, 1822: 106 (Ganges River).

Equula interrupta - Günther 1860 (Port Essington).

Material from Buffalo Creek area.

Caesionidae

Caesio cuning (Bloch, 1791)

Sparus cuning Bloch, 1791: 31 (Indonesia).

Caesio erythrogaster - Klunzinger 1879 (Port Darwin).

Additonal material from Fannie Bay.

Lutjanidae

Lutjanus argentimaculatus (Forsskål, 1775)

Sciaena argentimaculata Forsskål, 1775: 47 (Red Sea).

Mesoprion argentimaculatus - Klunzinger 1879 (Port Darwin).

Lutjanus roseigaster - Saville-Kent 1889 (Port Darwin).

Material from Nightcliff rockpools.

Lutjanus carponotatus (Richardson, 1842)

Mesoprion carponatatus Richardson, 1842: 28 (Port Essington).

Material from Channel Island.

Lutjanus erythropterus Bloch 1790

Lutjanus erythropterus Bloch 1790: 115 (Japan).

Mesoprion annularis - Klunzinger 1879 (Port Darwin).

Lutjanus johnii (Bloch, 1792)

Anthias johnii Bloch, 1792: 113 (Suratta).

Lutjanus johnii - Macleay 1878 (Port Darwin).

Material from off West Point, Woods Inlet and E of South Shell Island.

Lutjanus lemniscatus (Cuvier, 1828)

Serranus lemniscatus Valenciennes, 1828: 240 (Ceylon).

Lutjanus lemniscatus - Russell and Houston (Arafura Sea, NT).

Material from Channel Island area and Middle Arm.

Lutjanus malabaricus (Schneider, 1801)

Sparus malabaricus Schneider, 1801: 278 (Coromandel).

Lutjanus malabaricus - Taylor 1964 (Bartalumba Bay).

Material from stations 32 and 60, this survey.

Lutjanus russelli (Bleeker, 1849)

Mesoprion russelli Bleeker, 1849: 41 (Malay-Moluccan Archipelago).

? *Genyoroge notata* - Saville-Kent 1889 (Port Darwin).

Material from Rapid Creek, reef off Bullocky Point, NW side Channel Island and East Arm.

Nemipteridae

Pentapodus porosus (Valenciennes, 1830)

Pentapus porosus Valenciennes, 1830: 267 (probably Shark Bay, WA).

Maenoides? aurofrenatus Richardson, 1843: 8 (Talc Bay, Australia = Talc Head, Port Darwin).

Material from bottom end Woods Inlet.

Scaevius milii (Bory de Saint-Vincent, 1823)

Cantharus milii Bory de Saint-Vincent, 1823: 160 (Shark Bay, WA).

Scolopsis longulus - Richardson 1842 (Port Essington).

? *Scolopsis personatus* - Macleay 1878 (Port Darwin).

? *Scolopsis affinis* - Klunzinger 1879 (Port Darwin).

Material from off NW tip East Point and reef off Bullocky Point.

Scolopsis monogramma (Kuhl and van Hasselt, 1830)

Scolopsoides monogramma Kuhl and van Hasselt, 1830: 338 (Batavia).

Scolopsis temporalis - Paradice and Whitley 1927 (Pellew Islands).

Scolopsis regina - Taylor 1964 (Melville Bay, Yirrkala).

Gerreidae

Gerres abbreviatus Bleeker, 1850

Gerres abbreviatus Bleeker, 1850: 103 (Batavia).

Gerres profundus Macleay, 1878: 350 (Port Darwin, NT).

Parochusus cheverti - Whitley 1955 (Darwin).

Gerres filamentosus Cuvier, 1829

Gerres filamentosus Cuvier, 1829: 188 (Vizagapatam). - Richardson 1842 (Port Essington).

Gerres punctatus - Macleay 1878 (Port Darwin).

Additional material from Buffalo Creek area.

Gerres kapas Bleeker, 1851

Gerres kapas Bleeker, 1851: 482 (Batavia). - Collette 1983 (Croker Island).

Material from off East Point.

Gerres macracanthus Bleeker, 1854

Gerres macracanthus Bleeker, 1854: 195 (Batavia). - Waddy 1988 (Groote Eylandt).

Material from NW side Channel Island.

Gerres ovatus Günther, 1859

Gerres ovatus Günther, 1859: 343 (Australia). - Klunzinger 1879 (Port Darwin).

Gerres oyena (Forsskål, 1775)

Labrus oyena Forsskål, 1775: 35 (Suez and Djedda, Red Sea).

Gerres oyena - Klunzinger 1879 (Port Darwin).

Haemulidae

Plectorhinchus multivittatus (Macleay, 1878)

Diagramma multivittatum Macleay, 1879: 349 (Port Darwin).

Plectorhinchus multivittatus - Ogilby 1915 (Port Darwin at Spalding).

Plectorhinchus gibbosus (Lacépède, 1802)

Holocentrus gibbosus Lacépède, 1802: 344 (no type locality given).

Plectorhinchus nigrus - Taylor 1964 (Nightcliff, Darwin).

Additional material from East Point Reef and Fannie Bay.

Pomadasys argenteus (Forsskål, 1775)

Sciaena argentea Forsskål, 1775: 51 (Djedda).

Pomadasys hasta - Macleay 1878 (Port Darwin).

Additional material from Elizabeth River.

Pomadasys kaakan (Cuvier, 1830)

Pristipoma kaakan Cuvier, 1830: 244 (India).

? *Pristipoma* sp. - Saville-Kent 1889 (Port Darwin).

Pomadasys nageb - Paradice and Whitley 1927 (Darwin).

Additional material from NW side Channel Island, East Arm mudflats and Cullen Beach.

Lethrinidae

Lethrinus genivittatus Valenciennes, 1830

Lethrinus genivittatus Valenciennes, 1830: 360 (Indian Ocean).

Lethrinus nematacanthus - Russell and Houston 1989 (Arafura Sea).

Material from Vesteys Beach reef.

Lethrinus laticaudis Alleyne and Macleay, 1877

Lethrinus laticaudis Alleyne and Macleay, 1877: 276 (Percy Island, Queensland).

?*Lethrinus punctulatus* Macleay, 1878: 351 (Port Darwin).

?*Lethrinus richardsoni* - Klunzinger 1879 (Port Darwin).

Lethrinus fletus Whitley, 1943: 138 (Pellew Islands).

Macleay's *L. punctulatus* was apparently overlooked by Carpenter and Allen (1989) in their revision of the family; Sato (1978) identified it as *L. haematopterus*, as he did also with Klunzinger's record of *L. richardsoni*. Carpenter and Allen (1989) consider *L. haematopterus* to be a southern Japanese/Chinese endemic resembling *L. laticaudis*. Material from East Arm.

Lethrinus lentjan (Lacepède, 1802)

Bodianus lentjan Lacepède, 1802: 281 (Java).

Lethrinus fusciceps - Macleay 1878 (Port Darwin).

Lethrinus cocosensi - Saville-Kent 1889 (Port Darwin).

Additional material from Larrakeyah Naval Base and East Arm boat ramp.

Lethrinus nebulosus (Forsskål, 1775)

Sciaena nebulosa Forsskål, 1775: 52 (Red Sea).

Lethrinus nebulosus - Klunzinger 1879 (Port Darwin).

Additional material from E of South Shell Island and reef by East Arm ramp.

Dubious record (unable to assign to species):

Lethrinus reticulatus - Macleay 1884 (Port Darwin).

Sparidae

Acanthopagrus berda (Forsskål, 1775)

Sparus berda Forsskål, 1775: 32 (Red Sea).

Chrysophrys australis - Günther 1859 (Port Essington).

Chrysophrys hasta - Macleay 1878 (Port Darwin).

Additional material from NW side Channel Island, East Arm and Talc Head.

Sciaenidae

Nibea microgenys Sasaki, 1992

Nibea microgenys Sasaki, 1992: 5 (Embley River, Queensland).

Paratypes from Buffalo Creek, King Creek, Shoal Bay and Cullen Beach.

Nibea soldado (Lacepède, 1802)

Holocentrus soldado Lacepède, 1802: 344 ("Cayenne").

Sciaena leptolepis Ogilby, 1918: 87 (Croker Island, NT).

Material from Buffalo Creek and Cullen Beach.

Otolithes ruber (Schneider, 1801)

Johnius ruber Schneider, 1801: 75 (Tranquebar).

Otolithes ruber - Davis and May 1989 (East Alligator River mouth).

Material from Cullen Beach.

Protonibea diacanthus (Lacepède, 1802)

Lutjanus diacanthus Lacepède, 1802: 195 (locality not given).

Sciaena diacanthus - Taylor 1964 (Groote Eylandt).

Material from Cullen Beach.

Mullidae

Mulloides vanicolensis (Valenciennes, 1831)

Upeneus vanicolensis Valenciennes, 1831: 521 (Vanicolo).

Mulloidichthys auriflamma - Martin 1978 (Darwin area).

Upeneus tragula Richardson, 1846

Upeneus tragula Richardson, 1846: 220 (Canton).

Upeneoides tragula - Macleay 1878 (Port Darwin).
Additional material from East Point and reef by East Arm Ramp.

Monodactylidae

Monodactylus argenteus (Linnaeus, 1758)

Chaetodon argenteus Linnaeus, 1758: 272 (Habitat in Indiis).
Psettus argenteus - Macleay 1878 (Port Darwin).
Additional material from Ludmilla Creek and East Arm.

Leptobramidae

Leptobrama mulleri Steindachner, 1878

Leptobrama mulleri Steindachner, 1878: 388 (Queensland). - Lyle and Timms 1984 (NT).
Material from Fannie Bay.

Toxotidae

Toxotes chatareus (Hamilton, 1822)

Coius chatareus Hamilton, 1822: 101 (mouthes of the Ganges).
Toxotes jaculator - Castelnau 1873 (Port Darwin).
Toxotes chatareus - Taylor 1964 (Wood's Inlet, Darwin Harbour).
Additional material from NW side Channel Island and East Arm.

Ephippidae

Drepane punctata *(Linnaeus, 1758)*

Chaetodon punctatus Linnaeus, 1758: 273 (Asia).
Drepane punctata - Macleay 1878 (Port Darwin).
Additonal material from Buffalo Creek and Fannie Bay Rocks.

Platax batavianus Cuvier, 1831

Platax batavianus Cuvier, 1831: 225 (Batavia).
? *Platax orbicularis* - Richardson 1842 (Port Essington); - Macleay 1878 (Port Darwin).
? *Platax arthriticus* - Saville-Kent 1889 (Port Darwin).
Additional material from Darwin Harbour and Lee Point Reef.

Platax teira (Forsskål, 1775)

Chaetodon teira Forsskål, 1775: 60 (Red Sea).
Platax leschenaldi - Richardson 1842 (Talc Bay, NT).

Zabidius novemaculeatus (McCulloch, 1916)

Platax novemaculeatus McCulloch, 1916: 188 (NE of Gloucestor Head, Queensland).
Platax novemaculatus - Paradice and Whitley 1927 (Pellew Islands, NT).
Material from NW side Channel Island and Middle Arm.

Scatophagidae

Scatophagus argus *(Linnaeus, 1766)*

Chaetodon argus Linnaeus, 1766: 464 ("Habitat in India").
Scatophagus argus var. ocellatus Klunzinger, 1871: 566-567 (Port Darwin).
Scatophagus tetracanthus - Macleay 1878 (Port Darwin).
Additional material from Fannie Bay, East Arm and Woods Inlet.

Selenotoca multifasciatus (Richardson, 1846)

Scatophagus multifasciatus Richardson, 1846: 57 (King George's Sound, WA). - Macleay 1878 (Port Darwin).
Additional material from Cullen Beach, Vesteys Beach and East Arm.

Chaetodontidae

Chaetodon adiergastos *Seale, 1910*

Chaetodon adiergastos Seale, 1910: 116 (Bantayan Island,Philippines). - Martin 1978 (Darwin area).
Additional material from East Point Reef.

Chaetodon aureofasciatus Macleay, 1878

Chaetodon aureofasciatus Macleay, 1878: 351 (Port Darwin).
Additional material from East Point Reef, Nightcliff and Channel Island.

Chelmon marginalis Richardson, 1842

Chelmon marginalis Richardson, 1842: 29 (Port Essington, NT).
Chelmo tricinctus Castelnau 1875: 14 (Port Darwin).

Chelmo rostratus - Macleay 1878 (Port Darwin).
? *Chelmo truncatus* - Saville-Kent 1889 (Port Darwin).
Additional material from off East Point and Channel Island.

Chelmon muelleri (Klunzinger, 1879)

Chelmo mulleri Klunzingeri, 1879: 361 (no locality given , probably Port Darwin).
Additional material from bottom end Woods Inlet, NW tip East Point and reef off Bullocky Point.

Hemitaurichthys polyelpis (Bleeker, 1857)

Chaetodon polylepis Bleeker, 1857: 54 (Amboina).
Hemitaurichthys polylepis - Burgess 1978 ("also recorded from Darwin, Northern Territory").
Burgess' record is dubious; this is a species inhabiting clear coral-reef drop-offs, is highly conspicuous and has not been observed in the harbour.

Heniochus acuminatus (Linnaeus, 1758)

Chaetodon acuminatus Linnaeus, 1758: 272 ("Habitat in Indiis").
Heniochus macrolepidotus - Macleay 1878 (Port Darwin).

Parachaetodon ocellatus (Cuvier and Valenciennes, 1831)

Platax ocellatus Cuvier and Valenciennes, 1831: 229 (locality not given).
Chaetodon oligacanthus - Macleay 1878 (Port Darwin).
Additional material from Channel Island, East Arm boat ramp and Vesteys Beach.

Pomacanthidae

Chaetodontoplus duboulayi (Günther, 1867)

Holacanthus duboulayi Günther, 1867: 67 (north-west coast of Australia). - Macleay 1878 (Port Darwin).
Holacanthus douboulayi var. longitudinaliter-striata Klunzinger, 1879: 362 (Port Darwin).
Holacanthus darwiniensis Saville-Kent, 1889: 235 (Port Darwin).
Additional material from Channel Island.

Euxiphipops sexstriatus (Cuvier and Valenciennes, 1831)

Holacanthus sexstriatus Cuvier and Valenciennes 1831: 194 (Java). - Macleay 1878 (Port Darwin).

Pomacentridae

Abudefduf bengalensis (Bloch, 1787)

Chaetodon bengalensis Bloch, 1787: 110 (Bengal).
Glyphisodon palmeri - Paradice and Whitley 1927 (Pellew Islands).
Material from Dudley Point.

Abudefduf sexfasciatus (Lacepède 1801)

Labrus sexfasciatus Lacepède, 1801: 430 (Indo-Pacific Ocean).
Glyphisodon coelestinus - Macleay 1878 (Port Darwin).

Amphiprion clarkii (Bennett, 1830)

Anthias clarkii Bennett, 1830: 29 (Ceylon).
Amphiprion clarkii - Martin 1978 (Darwin area.).
Additional material from the harbour and Vesteys Beach.

Amphiprion ocellaris Cuvier, 1830

Amphiprion ocellaris Cuvier, 1830: 399 (Sumatra). - Allen 1991 (Darwin; black variety).
Amphiprion bicolor Castelnau, 1873: 92 (Port Darwin).
Amphiprion percula - Klunzinger 1879 (Port Darwin).
Addtional material from Darwin.

Amphiprion rubrocinctus Richardson, 1842

Amphiprion? rubrocinctus Richardson, 1842: 392 (near Depuch Island, WA).
Amphiprion Rüppelli Castelnau, 1873: 91 (Port Darwin).
Amphiprion bicinctus - Macleay 1881 (Port Darwin).
Additional material from the harbour and Channel Island.

Dischistodus darwiniensis (Whitley, 1928)

Dascyllus fasciatus Macleay, 1879: 361 (Port Darwin).

Pomacentrus darwiniensis Whitley, 1928: 297 (Port Darwin).

Dischistodus darwiniensis - Sin, Teo and Ng 1995 (Vesteys Beach, East Point).

Sin, Teo and Ng (1995) distinguish *D. darwiniensis* (previously referred to in literature as *D. fasciatus* (Cuvier) from *D. fasciatus* (Cuvier, 1830). Although Macleay's (1879) name is older than Whitley's, it is a homonym of *D. fasciatus* (Cuvier). Additional material from reef off Bullocky Point and Channel Island.

Neoglyphidodon melas (Cuvier, 1830)

Glyphisodon melas Cuvier, 1830: 472 (Java)

Abudefduf melanopus - Martin 1978 (Darwin area).

Pomacentrus amboinensis Bleeker, 1868

Pomacentrus amboinensis Bleeker, 1868: 334 (Amboina). - Martin 1978 (Darwin area).

Pomacentrus littoralis Cuvier, 1830

Pomacentrus littoralis Cuvier, 1830: 422 (Waigiou). - Günther 1862 (Port Essington).

Material from reef off Bullocky Point and Channel Island.

Pomacentrus milleri Taylor, 1964

Pomacentrus milleri Taylor, 1964: 261 (Yirrkala, near Cape Arnhem; paratypes from East Point Reef).

Additional material from off Dudley Point, NW tip East Point and Channel Island.

Pomacentrus tripunctatus Cuvier, 1830

Pomacentrus tripunctatus Cuvier, 1830: 421 (Vanicolo, Santa Cruz Islands).

Pomacentrus bilineatus Castelnau 1873: 89 (Port Darwin).

Pomacentrus trilineatus - Klunzinger 1879 (Port Darwin).

Stegastes obreptus (Whitley, 1948)

Pomacentrus obreptus Whitley, 1948: 275 (Monte Bello Islands, Western Australia).

Pomacentrus scolopsis - Macleay 1878 (Port Darwin).

Pomacentrus cyanospilus - Klunzinger 1879 (Port Darwin).

Mugilidae

Liza alata (Steindachner, 1892)

Mugil alata Steindachner, 1892: 133 (Madagascar).

Moolgarda (Planiliza) ordensis - Whitley 1951 (Melville Island and Darwin).

Liza melinoptera (Valenciennes, 1836)

Mugil melinoptera Valenciennes, 1836: 146 (Vanicolo).

Material from East Arm, Cullen Beach and Vesteys Beach. A new record for the Northern Territory.

Liza subviridis (Valenciennes, 1836)

Mugil subviridis Valenciennes, 1836: 115 (Ganges).

Mugil compressus - Klunzinger 1879 (Port Darwin).

Additional material from Cullen Beach, Ludmilla Creek and East Arm.

Liza vaigiensis (Quoy and Gaimard, 1825)

Mugil vaigiensis Quoy and Gaimard, 1825: 337 (Waigiou). - Macleay 1878 (Port Darwin).

Additional material from East Point and Cullen Beach.

Mugil cephalus Linnaeus, 1758

Mugil cephalus Linnaeus, 1758: 316 (European seas).

Mugil dobula - Macleay 1878 (Port Darwin).

No recent material of this species has been obtained in the Northern Territory so far.

Valamugil buchanani (Bleeker, 1853)

Mugil buchanani Bleeker, 1853: 99 (Hooghly River, India).

Valamugil buchanani - Taylor 1964 (Groote Eylandt).

Material from Ludmilla Creek and Woods Inlet.

Valamugil cunnesius (Valenciennes, 1836)

Mugil cunnesius Valenciennes, 1836: 114 (Moluccas).

Mugil longimanus - Paradice and Whitley 1927 (Pellew Islands).

Material from NW side Channel Island.

Valamugil seheli (Forsskål, 1775)

Mugil crenilabis seheli Forsskål, 1775: 14 (Lohaja, Red Sea).
Valamugil seheli - Thomson 1954 (from Darwin).

Dubious record.
Mugil Péronii - Macleay 1878 (Port Darwin). Thomson (1954) gives this as a record of *Liza argentea*, a temperate species. It is not known what Macleay actually was referring to.

Sphyraenidae

Sphyraena chrysotaenia Klunzinger, 1884

Sphyraena chrysotaenia Klunzinger, 1884: 128 (Red Sea).
? *Sphyraena langsar* - Macleay 1878 (Port Darwin).

Polynemidae

Eleutheronema tetradactylum (Shaw, 1804)

Polynemus tetradactylus Shaw, 1804: 155 (India).
Polynemus coecus Macleay, 1878: 354 (Port Darwin).
Additional material from creek at Mindil Beach and Cullen Beach.

Polydactylus macrochir (Günther, 1867)

Polynemus macrochir Günther, 1867: 60 (New South Wales).
Polynemus sheridani - Russell and Houston 1989 (Arafura Sea, NT).
Material from Cullen Beach.

Labridae

Choerodon cyanodus (Richardson, 1842)

Labrus cyanodus Richardson, 1842: 355 (Port Essington).
Material from NW side Channel Island and E of South Shell Island.

Choerodon monostigma (Ogilby, 1910)

Choirodon monostigma Ogilby, 1910: 102 (off Pine Peak and Cape Gloucester, Queensland).
Choerodon monostigma - Gloerfelt-Tarp and Kaiola 1984 (Arafura Sea, NT).
Material from five stations, this survey.

Choerodon schoenleinii (Valenciennes, 1839)

Cossyphus schoenleinii Valenciennes, 1839: 143 (Celebes).
Choerodon schoenleinii - Russell and Houston 1989 (Arafura Sea, NT).
Material from Darwin Harbour.

Choerodon vitta Ogilby, 1910

Choerodon vitta Ogilby, 1910: 13 (Aru Islands).
Material from off Dudley Point and NW tip East Point. New record for the Northern Territory.

Halichoeres dussumieri (Valenciennes, 1839)

Julis dussumieri Valenciennes, 1839: 478 (coast of Malabar).
Platyglossus immaculatus immaculatus Macleay, 1878: 362 (Port Darwin).
Additional material from reef off Bullocky Point, Channel Island and East Arm.

Scaridae

Scarus globiceps Valenciennes, 1840

Scarus globiceps Valenciennes, 1840: 242 (Tahiti).
Scarus aeruginosus - Taylor 1964 (Yirrkala, NT).
Juvenile specimen from Channel Island. From his colour description, it would seem that Taylor's record is a misidentification of *S. globiceps*.

Opistognathidae

Opisthognathus darwinensis Macleay, 1878

Opisthognathus darwinensis Macleay, 1878: 355 (Port Darwin).
Material from Fannie Bay, reef off Bullocky Point and N side Channel Island.

Opistognathus papuensis Bleeker, 1868

Opistognathus papuensis Bleeker, 1868: 333 (Waigiou).
Opisthognathus maculatus - Saville-Kent 1889 (Port Darwin).
Additional material from N of East Point, Woods Inlet and Catalina Island, East Arm.

Opistognathus n.sp.

Material of this new species, presently being described by W.F. Smith-Vaniz, from East Arm and Woods Inlet.

Trichonotidae

Trichonotus setigerus Bloch and Schneider, 1801

Trichonotus setiger Bloch and Schneider, 1801: 179 (Eastern India).

Trichonotus setigerus - Macleay 1878 (Port Darwin).

Trichonotus blochii - Macleay 1881 (Port Darwin).

Material from off Dudley Point is probably of this species.

Percophidae

Squamicreedia obtusa Rendahl, 1921

Squamicreedia obtusa Rendahl, 1921: 20 (Cape Jaubert, NW Australia). - Whitley 1956 (off Charles Point, NT).

Uranoscopidae

Ichthyscopus insperatus Mees, 1960

Ichthyscopus insperatus Mees, 1960: 54-55, figs 8-9 (Roebuck Bay, NW Australia).

One specimen from East Arm. A new record for the Northern Territory.

Blenniidae

Meiacanthus luteus Smith-Vaniz, 1987

Meiacanthus geminatus Smith-Vaniz, 1976: 95 (Darwin; = misidentification, in part).

Meiacanthus (Meiacanthus) luteus Smith-Vaniz 1987: 25 (Darwin Harbour, reef by East Arm boat ramp).

Additional material from East Arm Boat Ramp Reef and Channel Island.

Omobranchus ferox (Herre, 1927)

Petroscirtes ferox Herre, 1927: 277 (Lake Taal, Philippines).

Omobranchus ferox - Collette 1983 (East Vernon Island).

Material from Ludmilla Creek and NW side Channel Island.

Omobranchus lineolatus(Kner, 1868)

Petroscirtes lineolatus Kner, 1868: 29 (Candavu, Fiji).

Graviceps darwini Whitley, 1958: 47 (Port Darwin).

Omobranchus punctatus (Valenciennes, 1836)

Blennechis punctatus Valenciennes, 1836: 286 (in canal of Bombay).

Omobranchus punctatus - Springer and Gomon 1975 (Yirrkala, Groote Eylandt, Port Darwin).

Omobranchus rotundiceps (Macleay, 1881)

Petroscirtes rotundiceps Macleay, 1881: 9 (Port Jackson).

Omobranchus rotundiceps rotundiceps - Springer and Gomon 1975 (N of Darwin).

Material from Lee Point Reef and Channel Island.

Omobranchus verticalis Springer and Gomon, 1975

Omobranchus verticalis Springer and Gomon, 1975: 71 (Brisbane River, Queensland).

Material from NW side Channel Island and off East Arm boat ramp. New record for the Northern Territory.

Salarias sexfilum Günther, 1861

Salarias sexfilum Günther, 1861: 241 (no locality).

Salarias spaldingi Macleay, 1878: 359 (Port Darwin).

? *Salarias punctillatus* Klunzinger, 1879: 389 (Port Darwin).

Additional material from Channel Island.

Notograptidae

Notograptus guttatus Günther, 1867

Notograptus guttatus Günther, 1867: 63 (Cape York). - Macleay 1878 (Port Darwin).

Additional material from off NW tip East Point, Channel Island and East Arm.

Tripterygiidae

Enneapterygius gracilis Fricke, 1994.

Enneapterygius gracilis Fricke, 1994: 209-214 (Danger Point, Cobourg Peninsula, Northern Territory).

Paratypes from Nightcliff, East Point and Lee Point Reef.

Callionymidae

Callionymus grossi Ogilby, 1910

Callionymus grossi Ogilby, 1910: 43 (Moreton Bay, Queensland). - Fricke 1983 (East Point, Darwin; N of Melville Island; Buffalo Creek; Coral Bay).

Additional material from off East Point and reef by East Arm ramp.

Callionymus macdonaldi Ogilby, 1911

Callionymus macdonaldi Ogilby, 1911: 56 (Moreton Bay, Queensland). - Fricke 1983 (reef off Bullocky Point, Darwin; Shoal Bay).

Additional material from Fannie Bay, off East Point and East Arm mudflats.

Callionymus russelli Johnson, 1976

Callionymus russelli Johnson, 1976: 113 (Moreton Bay, Queensland).

Material from Fannie Bay, Frances Bay, S of Shell Island and reef by East Arm boat ramp. A new record for the Northern Territory.

Callionymus sphinx Fricke and Heckele, 1984

Callionymus sphinx Fricke and Heckele, 1984: 368 (Shoal Bay, Darwin).

Additional material from four stations, this survey.

Callionymus sublaevis McCulloch, 1926

Callionymus limiceps var sublaevis McCulloch, 1926: 204 (Hummocky Island, near Cape Capricorn, Queensland).

Callionymus sublaevis - Fricke 1983 (Buffalo Creek).

Additional material from three stations, this survey.

Dactylopus dactylopus Bennett, 1837

Dactylopus dactylopus Bennett, 1837: 310 (no locality given). - Waddy 1988 (Groote Eylandt).

Material from off East Point, bottom end Woods Inlet and reef by East Arm ramp.

Gobiidae: Gobiinae

Acentrogobius caninus *(Valenciennes, 1837)*

Gobius caninus Valenciennes, 1837: 86 (Java).

Acentrogobius caninus - Blaber *et al.* 1992 (Groote Eylandt).

Material from Ludmilla Creek, N side Channel Island and East Arm mudflats.

Acentrogobius viridipunctatus (Valenciennes, 1837)

Gobius viridipunctatus Valenciennes, 1837: 62 (Pondicherry).

Material from Ludmilla Creek, Rapid Creek and Woods Inlet. New record for the Northern Territory.

Amblygobius bynoensis Richardson, 1844

Amblygobius bynoensis Richardson, 1844: 1 (Bynoe Harbour, coasts of Western Australia).

Apocryptes bivittatus Macleay, 1878: 357 (Port Darwin).

Additional material from East Arm Boat Ramp Reef, Lee Point Reef and Nightcliff.

Amoya sp.

Material of an unidentified species from Station 91, this survey.

Amoya gracilis (Bleeker, 1875)

Ctenogobius gracilis Bleeker, 1875: 127 (Singapore).

Material from Ludmilla Creek, East Arm and Woods Inlet. New record for the Northern Territory.

Bathygobius fuscus (Rüppell, 1828)

Gobius fuscus Rüppell, 1828: 137 (Red Sea).

Gobius albopunctatus - Macleay 1878 (Port Darwin).

Material from Lee Point Reef and Nightcliff rockpools.

Bathygobius laddi (Fowler, 1931)

Rhinogobius laddi Fowler, 1931: 362 (Suva, Fiji).

Material from Lee Point Reef. New record for the Northern Territory.

Bryaninops amplus Larson, 1985

Bryaninops amplus Larson, 1985: 66 (Lizard Island, Queensland; paratypes from Coral Bay, Port Essington, NT).

Material from off East Point and Weed Reef.

Callogobius sp.

Material of an as yet unidentified species, from reef by East Arm boat ramp.

Cristatogobius sp.

Material from Channel Island, as yet unidentified to species. The genus has not been recorded before from the Northern Territory.

Cryptocentrus sp.

Material from off East Point and N side Channel Island, of one or two undescribed species; description in preparation by D. Hoese.

Cryptocentrus insignitus (Whitley, 1956)

Batman insignitus Whitley, 1956: 36 (Port Darwin).

Additional material from N of East Point and Catalina Island, East Arm.

Drombus sp. 8

Material of this species from East Arm mudflats and Woods Inlet.

Drombus globiceps (Hora, 1923)

Ctenogobius globiceps Hora, 1923: 744 (Chilka Lake).

Drombus globiceps - Blaber *et al.* 1992 (Groote Eylandt).

Material from Darwin Harbour.

Drombus ocyurus (Jordan and Seale, 1907)

Rhinogobius ocyurus Jordan and Seale, 1907: 42 (Cavite, Philippines).

Drombus ocyurus - Blaber *et al.* 1992 (Groote Eylandt).

Material from bottom end Woods Inlet and East Arm mudflats.

Drombus triangularis (Weber, 1911)

Gobius triangularis Weber, 1911: 150 (Ambon).

Drombus triangularis - Blaber *et al.* 1992 (Groote Eylandt).

Material from East Arm boat ramp reef, Lee Point Reef and Ludmilla Creek.

Eviota queenslandica Whitley, 1932

Eviota viridis queenslandica Whitley, 1932: 301 (Batt Reef, Queensland).

Eviota queenslandica - Lachner and Karnella 1980 (Groote Eylandt, Yirrkala, NT).

Material from Lee Point Reef, East Point and Channel Island.

Favonigobius melanobranchus (Fowler, 1934)

Rhinogobius melanobranchus Fowler, 1934: 9 (Denpasar, Bali).

Favonigobius melanobranchus - Blaber *et al.* 1992 (Groote Eylandt).

Material from Bullocky Point sandflats, Ludmilla Creek and Rapid Creek.

Glossogobius biocellatus (Valenciennes, 1837)

Gobius biocellatus Valenciennes, 1837: 73 (Pondicherry).

Glossogobius biocellatus - Collette 1983 (Croker Island, NT).

Material from Ludmilla Creek, N side Channel Island and East Arm mudflats.

Glossogobius circumspectus (Macleay, 1883)

Gobius circumspectus Macleay, 1883: 267 (Milne Bay).

Material from Ludmilla Creek, S end Channel Island and East Arm mudflats. New record for the Northern Territory.

Gobiopsis macrostoma Steindachner, 1861

Gobiopsis macrostoma Steindachner, 1861: 291 (Bombay). - Davis and May 1989 (East Alligator River mouth).

Material from Lee Point Reef.

Istigobius nigroocellatus (Günther, 1873)

Gobius nigroocellatus Günther, 1873: 101 (Bowen, Queensland).

Innoculus nigroocellatus - Whitley 1952 (Melville Bay and Cape Arnhem).

Material from off NW tip East Point and reef off Bullocky Point.

Istigobius ornatus (Rüppell, 1830)

Gobius ornatus Rüppell 1830: 135 (Massawa). - Paradice and Whitley 1927 (Adam Bay, NT).

Material from Lee Point Reef and Nightcliff.

Mahidolia mystacina (Valenciennes, 1837)

Gobius mystacinus Valenciennes, 1837: 124 (Java).

? *Gobius maxillaris* Macleay 1878: 357 (Port Darwin).

Material from N side Channel Island and East Arm.

Myersina macrostoma Herre, 1934

Myersina macrostoma Herre, 1934: 90 (Culion Harbour, Philippines).

Material from Garden Point, East Arm mudflats and N side Channel Island. New record for the Northern Territory.

Oplopomus caninoides (Bleeker, 1852)

Gobius caninoides Bleeker, 1852: 274 (Amboina).

Material from off Mindil Beach and NW of Middle Point. New record for the Northern Territory.

Palutrus pruinosus (Jordan and Seale, 1906)

Eviota pruinosa Jordan and Seale, 1906: 391 (Pago Pago, Samoa).

Material from Channel Island, Bullocky Point sandflats and N side Channel Island. New record for the Northern Territory.

Pandaka lidwilli (McCulloch, 1917)

Gobius lidwilli McCulloch, 1917: 185 (Cowan Creek, New South Wales).

Material from Ludmilla Creek, Vesteys Beach and Catalina Island, East Arm. New record for the Northern Territory.

Paragobiodon echinocephalus (Rüppell, 1831)

Gobius echinocephalus Rüppell 1831: 136 (Massowah, Red Sea).

Paragobiodon echinocephalus - Koumans 1953 (Port Darwin).

This shrub-coral commensal has not been reported from the Northern Territory since.

Priolepis nuchifasciata (Günther, 1878)

Gobius nuchifasciatus Günther, 1878: 90 (Bowen, Queensland).

Priolepis nuchifasciata - Winterbottom and Burridge 1993 (Darwin).

Additional material from Channel Island, Lee Point Reef and Weed Reef.

Silhouettea evanida Larson and Miller, 1986

Silhouettea evanida Larson and Miller, 1986: 111 (Mindil Beach, Darwin).

Additional material from Mindil Beach and Vesteys Beach.

Valenciennea alleni Hoese and Larson, 1994

Valenciennea alleni Hoese and Larson, 1994: 13 (Haggerstone Island, Queensland; paratypes from reef flat off Dudley Point, Fannie Bay).

Valenciennea muralis Valenciennes, 1837)

Eleotris muralis Valenciennes, 1837: 253 (Tikopia, Santa Cruz Archipelago).

Valenciennea muralis - Hoese and Larson, 1994 (Cape Don, Sandy Island, Port Bradshaw, Yirrkala, NT).

Material from East Arm boat ramp reef, Lee Point reef and Nightcliff.

Vanderhorstia sp.

An as yet unidentifed species of this genus from the N side Channel Island.

Yongeichthys nebulosus (Forsskål, 1775)

Gobius nebulosus Forsskål, 1775: 24 (Red Sea).

Gobius criniger - Günther 1861 (Port Essington).

Yongeichthys nebulosus - Blaber *et al.* 1992 (Groote Eylandt).

Material from Bullocky Point sandflats, East Arm boat ramp reef and Lee Point.

Gobiidae
Gobionellinae

Calaniana n. sp.

Material of a new species associated with mangroves, from East Arm. The species is being described by the senior author.

Chlamydogobius ranunculus Larson, 1995

Chlamydogobius ranunculus Larson, 1995: 38-42 (buffalo wallow, Beatrice Lagoon, Adelaide River, NT).

Paratypes from Leanyer Swamp. Additional material from Darwin River; tidal.

Gnatholepis sp.

Gnatholepis knishti - Collette 1983 (East Vernon Is.).

This species is not yet identified; the genus *Gnatholepis* is in need of revision. Material from Bullocky Point sandflats, East Arm boat ramp reef and off East Point.

Gobiopterus sp.

Material from creek at Ludmilla Creek, Elizabeth River mouth, East Arm and Woods Inlet. This genus is in need of revision; these specimens may represent an undescribed species.

Hemigobius hoevenii (Bleeker, 1851)

Gobius hoevenii Bleeker, 1851: 426 (River Sambas, Borneo).

Specimens from Leanyer Swamp and Elizabeth River mouth. New record for the NT.

Mugilogobius sp. 9

Material of an undescribed species of this genus from Ludmilla Creek, Rapid Creek, Vesteys Beach Creek and Elizabeth River mouth.The genus is under revision by the senior author.

Mugilogobius sp.13

This is an undescribed species (presently being described by the senior author) known only from tropical northern Australia. Harbour material from Casuarina Beach Reserve and creek at Vesteys Beach.

Mugilogobius platystomus (Günther, 1872)

Gobius platystoma Günther, 1872: 664, pl. 63, fig. B (Port Mackay, Queensland, Australia).

Material from creek by Darwin High School. New record for the Northern Territory.

Pseudogobius sp. 2

Pseudogobius sp. - Blaber *et al.* 1992 (Groote Eylandt).

Material from Ludmilla Creek, N side Channel Island and creek at Elizabeth River Mouth. This is possibly *Pseudogobius poicilosoma* (Bleeker); a revision of this genus by the senior author is in progress.

Pseudogobius sp.11

Material of an undescribed species associated with mangroves, from Channel Island. The species will be described by the senior author.

Redigobius bikolanus (Herre, 1927)

Vaimosa bikolana Herre, 1927: 151 (Legaspi, Philippines).

Material from Ludmilla Creek, East Arm and S end Channel Island. A new record for the Northern Territory. This genus is under revision by the senior author; the name may possibly change.

Redigobius chrysosoma (Bleeker, 1875)

Lophogobius chrysosoma Bleeker, 1875: 114 (Bandjermasin, Borneo).

Redigobius chrysosoma - Larson and Martin 1990 (Berry Springs, NT).

Material from Tumbling Waters, Elizabeth River; tidal.

Gobiidae
Butinae

Bostrychus sinensis Lacepède, 1801

Bostrychus sinensis Lacepède, 1801: 140 (China).

Material from Nightcliff rocks, Ludmilla Creek and NW side Channel Island. New record for the Northern Territory.

Bostrychus zonatus Weber, 1908

Bostrychus zonatus Weber, 1908: 259 (Merauke River, New Guinea).

Material from Coconut Grove and Leanyer Swamp. New record for the Northern Territory.

Butis butis (Hamilton, 1822)

Cheilodipterus butis Hamilton, 1822: 57 (Ganges River below Calcutta).

Butis butis - Blaber *et al.* 1992 (Groote Eylandt).

Material from Ludmilla Creek, Vesteys Beach boat ramp, S end Channel Island and East Arm.

***Butis koilomatodon* (Bleeker, 1849)**

Eleotris koilomatodon Bleeker, 1849: 21 (Madura, Indonesia).

Prionobutis microps - Rendahl 1922 (Daly River, NT).

Prionobutis (Themistocles) wardi Whitley, 1939b: 296 (Point Charles, near Darwin).

Material from Francis Bay, East Arm, Ludmilla Creek, Woods Inlet and reef by East Arm boat ramp.

***Incara multisquamata* Rao, 1971**

Incara multisquamata Rao, 1971: 329: (Godavari estuary, India).

Material from Leanyer Swamp and NW side Channel Island. New record for the Northern Territory.

***Ophiocara porocephala* (Valenciennes, 1837)**

Eleotris porocephala Valenciennes, 1837: 237 (Seychelles and New Ireland).

Agonostoma darwiniense Macleay, 1878: 360 (Port Darwin).

Material from Cullen Beach and Ludmilla Creek.

***Oxyeleotris* sp.**

Eleotris macrodon - Klunzinger 1879 (Port Darwin).

Oxyeleotris sp. - Larson and Martin 1990 (Leanyer Swamp, near Darwin).

From the counts and description given by Klunzinger, his record is very likely to be of this apparently undescribed species.

Gobiidae
Eleotridinae

***Hypseleotris compressa* (Krefft, 1864)**

Eleotris compressus Krefft, 1864: 184 (Clarence River, New South Wales).

Eleotris modestus Castelnau, 1873: 85 (Port Darwin).

Eleotris reticulatus Klunzinger, 1879: 385 (Port Darwin).

Additional material from Coconut Grove.

Gobiinae
Oxudercinae

***Apocryptodon madurensis* (Bleeker, 1849)**

Apocryptes madurensis Bleeker, 1849: 35 (Java).

Apocryptodon madurensis - Murdy 1989 (Northern Territory).

Material from Ludmilla Creek, N side Channel Island, East Arm mudflats and Woods Inlet.

***Boleophthalmus birdsongi* Murdy, 1989**

Boleophthalmus birdsongi Murdy, 1989: 12 (Liverpool River, NT; other material from Darwin, Milingimbi, Elizabeth River, Gunn Point).

Additional material from Ludmilla Creek, Rapid Creek and Vesteys Beach Creek.

***Oxuderces wirzi* (Koumans, 1938)**

Apocryptodon wirzi Koumans, 1938: 26 (Papua New Guinea).

Oxuderces wirzi - Murdy 1989 (Northern Territory).

Material from Ludmilla Creek.

***Periophthalmodon freycineti* (Valenciennes, 1837)**

Periophthalmus freycineti Valenciennes, 1837: 197 (Timor).

Periophthalmodon freycineti - Murdy 1989 (Northern Territory).

Material from Buffalo Creek.

***Periophthalmus argentilineatus* Valenciennes, 1837**

Periophthalmus argentilineatus Valenciennes, 1837: 191 (Irian Jaya and Moluccas). - Murdy 1989 (Northern Territory).

Material from Ludmilla Creek, Rapid Creek and Elizabeth River mouth.

***Periophthalmus kalolo* Lesson, 1830**

Periophthalmus kalolo Lesson, 1830: 146 (Waigiou).

Material from mouth of Ludmilla Creek. This is a new record for the Northern Territory.

***Periophthalmus novaeguineaensis* Eggert, 1935**

Periophthalmus cantonensis novaeguineaensis Eggert, 1935: 61 (Merauke, New Guinea).

Periophthalmus novaeguineaensis - Murdy 1989 (Northern Territory).

Material from Ludmilla Creek, Nightcliff shore reef and N side Channel Island.

Periophthalmus sp.

Periophthalmus koelreuteri - Macleay 1878 (Port Darwin).

Macleay's record of *koelreuteri* is an error; it is not known to which species of *Periophthalmus* he was referring.

Scartelaos histophorus (Valenciennes, 1837)

Boleophthalmus histophorus Valenciennes, 1837: 210 (Bombay).

Apocryptes macrophthalmus Castelnau, 1873: 87 (Port Darwin).

Gobiosoma guttulatum Macleay, 1878: 357 (Port Darwin).

Additional material from Ludmilla Creek, Nightcliff and Cullen Beach.

Gobiidae

Amblyopinae

Brachyamblyopus rubristriatus (Saville-Kent, 1889)

Amblyopus rubristriatus Saville-Kent, 1889: 235, fig.3 (Cambridge Gulf and Port Darwin).

Additional material from Woods Inlet.

Saville-Kent spelled the name of this species as *rubri-lineatus* on page 223 of his original description, then subsequently spelled it as *rubristriatus* on pages 235 and 240. The latter spelling was likely to have been his intention.

Taenioides gracilis (Valenciennes, 1837)

Amblyopus gracilis Valenciennes, 1837: 166 (Pondicherry).

Taenioides gracilis - Collette 1983 (Croker Island).

Material from Francis Bay, Ludmilla Creek, and N side Channel Island is probably of this species; the genus is in need of revision.

Microdesmidae

Parioglossus palustris (Herre, 1945)

Andameleotris palustris Herre 1945: 2 (Zamboanga, Philippines).

Parioglossus palustris - Rennis and Hoese 1985 (East Arm, Darwin Harbour).

Additional material from off East Arm boat ramp, Creek H at East Arm, and Mickett Creek.

Acanthuridae

Acanthurus xanthopterus Valenciennes, 1835

Acanthurus xanthopterus Valenciennes, 1835: 215 (Seychelles). - Martin 1978 (Darwin area).

Acanthurus grammoptilus Richardson, 1843

Acanthurus grammoptilus Richardson, 1843: 176 (Coral Bay, Port Essington).

Acanthurus annularis - Saville-Kent 1889 (Port Darwin).

Additional material from the harbour, Fannie Bay and Larrakeyah Naval Base.

Siganidae

Siganus fuscescens (Houttuyn, 1782)

Siganus fuscescens Houttuyn, 1782: 333 (Japan).

Teuthis nebulosa - Günther 1861 (Port Essington).

? *Teuthis sutor* - Klunzinger 1879 (Port Darwin).

? *Teuthis guttatus* - Saville-Kent 1889 (Port Darwin).

Material from Station 71, this survey.

Siganus javus (Linnaeus, 1766)

Teuthis javus Linnaeus, 1766: 507 (Java).

Siganus javus - Woodland 1990 (Table Head, Port Essington, Northern Territory).

Material from Darwin Harbour, off Naval Base.

Siganus lineatus (Cuvier and Valenciennes, 1835)

Amphacanthus lineatus Cuvier and Valenciennes, 1835: 310 (Waigiou).

Siganus lineatus - Paradice and Whitley 1927 (Cape Wessell and Pellew Islands). - Woodland 1990 (Port Darwin).

Additional material from Channel Island.

Siganus virgatus (Cuvier and Valenciennes, 1835)

Amphacanthus virgatus Cuvier and Valenciennes, 1835: 133 (Java).

Siganus notosticta Richardson, 1843: 172 (Port Essington, NT).

Teuthis notosticta - Günther 1861 (Port Darwin).

Trichiuridae

Trichiurus lepturus Linnaeus, 1758

Trichiurus lepturus Linnaeus, 1758: 246 (South Carolina, North America). - Russell and Houston 1989 (Arafura Sea, NT).

Material from Shoal Bay.

Lepturacanthus savala Cuvier, 1829

Trichiurus savala Cuvier, 1829: 219 ("Mer des Indes"). - Macleay 1878 (Port Darwin).

Scombridae

Rastrelliger kanagurta (Cuvier, 1817)

Scomber kanagurta Cuvier, 1817: 313 (India).

Rastrelliger canagurta - Munro 1958 (Darwin Harbour).

Scomberomorus queenslandicus Munro, 1943

Scomberomorus (Cybium) queenslandicus Munro, 1943: 82 (Cape Cleveland, Queensland).

Cybium queenslandicus Whitley 1954 (near Parry Shoals, NT).

Material from Old Darwin Wharf.

Scomberomorus semifasciatus (Macleay 1884)

Cybium semifasciatum Macleay 1884: 205 (Burdekin River, Queensland).

Scomberomorus semifasciatus - Munro 1943 (Port Darwin).

PLEURONECTIFORMES

Bothidae

Arnoglossus sp.

Material from off Cullen Beach, Woods Inlet, off Mindil Beach and S of Dudley Point.

Arnoglossus aspilos praeteritus Whitley, 1950

Arnoglossus aspilos praeteritus Whitley, 1950: 32 (Western Australia between Cape Jaubert and Wallal; paratype(s) from off Darwin).

Arnoglossus intermedius (Bleeker,1866)

Platophrys (Arnoglossus) intermedius Bleeker, 1866: 47 (Menado?, Celebes).

Material from four stations, this survey. New record for the Northern Territory.

Pseudorhombus arsius (Hamilton, 1822)

Pleuronectes arsius Hamilton, 1822: 128 (Ganges).

Rhombus lentiginosus Richardson, 1843: 495 (Port Essington).

Material from East Point reef area, Ludmilla Creek and NW of Middle Point.

Pseudorhombus elevatus Ogilby, 1912

Pseudorhombus elevatus Ogilby, 1912: 45 (Moreton Bay). - Russell and Houston 1989 (Arafura Sea, NT).

Material from S of Dudley Point, and from three stations, this survey.

Pseudorhombus jenynsii (Bleeker, 1855)

Platessa jenynsii Bleeker, 1855: 15 (King George Sound, WA).

Material from reef by East Arm boat ramp, and from this survey. New record from the Northern Territory. Norman (1934) considers that there may be several species included under this name.

Soleidae

Aseraggodes sp.

Material of an as yet unidentified species from Ludmilla Creek.

Dexillichthys muelleri (Stenidachner, 1879)

Synaptura muelleri Steindachner, 1879: 4 (Arafura Sea).

Dexillichthys muelleri - Russell and Houston 1989 (Arafura Sea, NT).

Material from Station 181.

Paradicula setifer (Paradice, 1927)

Synaptura setifer Paradice, 1927: 101 (Port Darwin).

Additional material from East Arm mudflats and Woods Inlet.

Pardachirus poropterus (Bleeker, 1851)

Achirus poroptera Bleeker, 1851: 410 (Batavia and Padang, Java).
Solea (Achirus) poropterus? - Klunzinger 1879 (Port Darwin).
Pardachirus klunzingeri - Weber 1908 (Port Darwin).
Achirus rautheri Chabanaud, 1931: 95 (Port Darwin).
Material from Ludmilla Creek.

Phyllichthys sclerolepis (Macleay, 1878)

Synaptura sclerolepis Macleay, 1878: 363 (Port Darwin).
Additional material from East Arm boat ramp reef and Lee Point reef.

Rendahlia jaubertensis (Rendahl, 1921)

Achirus jaubertensis Rendahl, 1921: 16 (Cape Jaubert, NW Australia).
Rendahlia jaubertensis - Munro 1958 (NT).
Material from Fannie Bay.

Dubious record:
Synaptura nigra - Saville-Kent 1889 (Port Darwin).
This is a synonym of the temperate species *Synaptura orientalis* (Bloch and Schneider 1801). It is unclear to what species Saville-Kent was referring.

Cynoglossidae

Cynoglossus bilineatus (Lacépède, 1802)

Achirus bilineatus Lacépède, 1802: 6 (China and the East Indies).
Cynoglossus sindensis - Ogilby 1910 (Croker Island).
Cynoglossus bilineatus - Chapleau, Renaud and Kailola 1991: 243 (Darwin area, NT).

Cynoglossus maculipinnis Rendahl, 1921

Cynoglossus maculipinnis Rendahl, 1921: 17 (NW Australia). - Taylor 1964 (Port Bradshaw).
Material from stations 123 and 181, this survey.

Cynoglossus puncticeps (Richardson, 1846)

Plagusia puncticeps Richardson, 1846: 280 (China).
Material from Station 33, this survey. New record for the Northern Territory.

Paraplagusia bilineata (Bloch, 1787)

Pleuronectes bilineata Bloch, 1787: 29 (Chinese waters).
Plagusia guttata Macleay, 1878: 362 (Port Darwin).
Plagusia japonica - Klunzinger 1879 (Port Darwin).
Additional material from Cullen Beach and reef off Bullocky Point.

Paraplagusia longirostris Chapleau, Renaud and Kailola, 1991

Paraplagusia longirostris Chapleau, Renaud and Kailola, 1991: 240 (Bonaparte Gulf, WA; non-type material from Darwin area).

Paraplagusia sinerama Chapleau and Renaud, 1993

Paraplagusia sinerama Chapleau and Renaud, 1993: 798 (mouth of Buffalo Creek, NT).

Triacanthidae

Triacanthus biaculeatus (Bloch, 1786)

Balistes biaculeatus Bloch, 1786: 17 (East Indies).
Triacanthus brevirostris - Klunzinger 1879 (Port Darwin).
Material from Buffalo Creek area.

Tripodichthys angustifrons (Hollard, 1954)

Triacanthus angustifrons Hollard, 1954: 45 (mer des Indies).
Triacanthus biaculeatus - Paradice and Whitley 1927 (Pellew Islands and Darwin).
Material from Buffalo Creek area.

PLEURONECTIFORMES

Balistidae

Canthidermis maculatus (Bloch, 1786)

Balistes maculatus Bloch, 1786: 25 (American waters).
Specimen from off East Point (rafting under floating timber). New record for the Northern Territory.

Monacanthidae

Anacanthus barbatus (Gray, 1831)

Balistes (Anacanthus) barbatus Gray, 1831: 8 (Singapore).

Psilocephalus barbatus - Paradice and Whitley 1927 (Pellew Islands, NT).

Material from Woods Inlet.

Monacanthus chinensis (Osbeck, 1765)

Balistes chinensis Osbeck, 1765: 147 (China).

Monacanthus megalurus - Klunzinger 1879 (Port Darwin).

Monacanthus chinensis - Macleay 1878 (Port Darwin).

Material from East Point reef and Fannie Bay.

Paramonacanthus choirocephalus (Bleeker, 1852)

Monacanthus choirocephalus Bleeker, 1852: 19 (Batavia).

Paramonacanthus japonicus - Russell and Houston 1989 (Arafura Sea, NT).

Material from NW of Middle Point, and from 19 stations, this survey.

Dubious record.

Monacanthus trachylepis - Klunzinger 1879 (Port Darwin).

Ostraciidae

Lactoria cornuta (Linnaeus, 1758)

Ostracion cornutus Linnaeus, 1758: 331 (India).

Ostracion cornutus - Saville-Kent 1889 (Port Darwin).

Lactoria cornuta is known from the NT by a single specimen from near Jones Shoal, so Saville-Kent's record from the harbour may be valid.

Rhynchostracion nasus (Bloch 1785)

Ostracion nasus Bloch, 1785: 349 (Nile)

Ostracion cubicus - Macleay 1878 (Port Darwin.).

Material from East Point, bottom end Woods Inlet and reef by East Arm boat ramp.

Rhynchostracion rhinorhynchus Bleeker, 1852

Ostracion rhinorhynchus Bleeker, 1852: 34 (East Indies). - Klunzinger 1879 (Port Darwin).

Material from Darwin Harbour Wharf.

Dubious records:

Aracana aurita - Klunzinger 1879 (Port Darwin).

Aracana ornata - Klunzinger 1879 (Port Darwin).

Klunzinger's records are very likely based on specimens from Port Philip (localities became confused).

Tetraodontidae

Arothron manilensis (Proce, 1822)

Tetrodon manilensis de Proce, 1822: 130 (Bay of Manila).

Tetrodon virgatus - Macleay 1878 (Port Darwin).

Additional material from East Point reef, North Casuarina Beach and Elliott Point.

Arothron stellatus (Bloch and Schneider, 1801)

Tetrodon stellatus Bloch and Schneider, 1801: 503 (seas around Mauritius).

Arothron stellatus - Russell and Houston 1989 (Arafura Sea, NT).

Material from Fannie Bay and Middle Arm.

Chelonodon patoca (Hamilton, 1822)

Tetrodon patoca Hamilton, 1822: 7 (Ganges).

Tetraodon patoca - Macleay 1878 (Port Darwin).

Additional material from Fannie Bay, Ludmilla Creek and East Arm.

Lagocephalus spadiceus (Richardson, 1845)

Tetrodon spadiceus Richardson, 1845: 123 (Canton, China).

Lagocephalus spadiceus - Pender, Willing and Ramm 1992 (off Melville Island, Arnhem Land).

Material from Buffalo Creek area.

Marilyna darwinii (Castelnau, 1873)

Tetraodon darwinii Castelnau, 1873: 94 (Port Darwin).

Tetrodon fasciatus Macleay, 1878: 365 (Port Darwin)

Additional material from N side Channel Island and East Arm.

Marilyna meraukensis (de Beaufort, 1955)

Sphoeroides meraukensis de Beaufort, 1955: 53 (Merauke River, Papua New Guinea).

Marilyna meraukensis - Hardy 1982 (Mickett Creek, Shoal Bay, NT).

Material from Cullen Beach.

Torquigener pallimaculatus Hardy, 1983

Torquigener pallimaculatus Hardy, 1983: 20 (Princess Charlotte Bay, Queensland; paratype from Burns Shoal, NT)

Material from Station 126, this survey.

Dubious records:

Tetrodon hamiltoni - Klunzinger 1879 (Port Darwin).

According to Hardy (1983) this is a misidentification; the species does not live in the Northern Territory (he does not offer a solution).

Tetrodon richei - Klunzinger 1879 (Port Darwin).

According to Hardy (1981), this record cannot be now postively identified.

Diodontidae

Diodon holacanthus Linnaeus, 1758

Diodon holacanthus Linnaeus, 1758: 335 (India). - Russell and Houston 1989 (Arafura Sea, NT).

Material from Fannie Bay and East Point.

Diodon liturosus Shaw, 1804

Diodon liturosus Shaw, 1804: 436 (Indian Seas).

Diodon maculatus - Macleay 1878 (Port Darwin).

Additional material from shore reef at Lee Point.

Tragulichthys jaculiferus (Cuvier, 1818)

Diodon jaculiferus Cuvier, 1818: 130 (Indian Ocean).

Tragulichthys jaculiferus - Gloerfelt-Tarp and Kailola 1984 (Arafura Sea, NT).

Material from station 183, this survey.

DISCUSSION

415 species, from 95 families, are recorded from Darwin Harbour. Of these 415 species, 31 are new records for the Northern Territory. Fifty-three species have been described from localities within the Harbour, and 19 of these are still considered to be valid species today. On the Northern Territory coastline, Port Essington and Darwin Harbour are two areas in which the fish fauna is fairly well known. Approximately 450 species (from about 100 families) are known from the Cobourg Peninsula Marine Park area, which includes Port Essington and a detailed checklist for the Marine Park is in progress (Larson and Russell, in prep.).

The Harbour is faunistically similar to Port Essington (the type locality for 14 valid species of fish). The most speciose family in the Harbour by far is the Gobiidae (66 species among six subfamilies), followed by the Apogonidae (21 species), the Syngnathidae (18 species) and the Pomacentridae (12 species). These dominant four families are all "coral reef" families.

The high number of syngnathid (pipefish) species in a relatively small area is interesting, and possibly reflects the juxtaposition of estuarine mangrove and marine reef habitats in the harbour. The entire Australian syngnathid fauna is very diverse, and although it is probably better known for its 14 endemic temperate genera (such as the seadragons *Phyllopteryx* and *Phycodurus*), it includes 30 species and subspecies from the north-western region (including the offshore coral atolls and reefs) (Dawson 1985). Darwin Harbour contains over half the known north-western pipefish fauna.

When the fish fauna of Darwin Harbour is compared to that of Port Essington, Arafura Sea, southern Gulf of Carpentaria, Gulf of Papua, southern Great Barrier Reef and coastal Queensland (Table 3), it is apparent that the diversity of species of gobiids, apogonids and pomacentrids show greatest similarity with that of Port Essington and the southern Great Barrier Reef. In contrast to the southern Barrier Reef, however, Darwin Harbour has significantly fewer coral reef-associated species: only five labrids, seven blenniids and seven chaetodontids.

Table 3. Top 10 most speciose families (and number of species per family) in Darwin Harbour, compared with Port Essington, the Arafura Sea, southern Gulf of Carpentaria, Gulf of Papua, southern Great Barrier Reef, coastal Queensland. Data for Port Essington is preliminary, taken from Larson and Russell (in prep.); data for all other regions from Russell and Houston (1989).

Darwin Harbour		Port Essington (preliminary data)		Arafura Sea		S Gulf of Carpentaria		Gulf of Papua		S Great Barrier Reef		coastal Queensland	
Gobiidae	(66)	Gobiidae	(60)	Carangidae	(38)	Carangidae	(21)	Carangidae	(29)	Gobiidae	(104)	Scorpaenidae	(23)
Apogonidae	(21)	Carangidae	(20)	Lutjanidae	(21)	Clupeidae	(13)	Scorpaenidae	(17)	Labridae	(69)	Carangidae	(17)
Syngnathidae	(18)	Apogonidae	(18)	Carcharhinidae	(19)	Scorpaenidae	(12)	Clupeidae	(15)	Pomacentridae	(69)	Bothidae	(16)
Pomacentridae	(12)	Blenniidae	(14)	Leiognathidae	(16)	Apogonidae	(12)	Sciaenidae	(14)	Blenniidae	(40)	Tetraodontidae	(13)
Serranidae	(12)	Pomacentridae	(12)	Nemipteridae	(16)	Leiognathidae	(12)	Ariidae	(13)	Apogonidae	(33)	Platycephalidae	(12)
Carangidae	(10)	Serranidae	(12)	Platycephalidae	(15)	Gobiidae	(12)	Engraulididae	(12)	Serranidae	(32)	Apogonidae	(11)
Leiognathidae	(9)	Tetraodontidae	(10)	Serranidae	(15)	Soleidae	(12)	Tetraodontidae	(12)	Chaetodontidae	(32)	Callionymidae	(8)
Hemiramphidae	(9)	Platycephalidae	(10)	Scorpaenidae	(14)	Ariidae	(11)	Leiognathidae	(11)	Acanthuridae	(25)	Monacanthidae	(7)
Ariidae	(8)	Leiognathidae	(10)	Mullidae	(14)	Sciaenidae	(9)	Lutjanidae	(11)	Muraenidae	(23)	Triacanthodidae	(7)
Mugilidae	(8)	Scorpaenidae	(9)	Bothidae	(13)	Tetraodontidae	(9)	Apogonidae	(10)	Scaridae	(22)	Triglidae	(7)

Port Essington, in contrast, has 14 species of blenniids and 10 tetraodontids, probably reflecting great extent of reefs (high numbers of blenniids, gobiids) and greater trawling activity offshore (e.g. carangid and tetraodontid numbers). The high diversity of syngnathid species appears to be unique to the Harbour (for example, Port Essington has only seven species recorded so far: Larson and Russell, in prep.).

The diversity of serranids, carangids, leiognathids and ariids in the Harbour is similar to that of the Arafura Sea and the Gulf of Papua, and to a lesser extent, Port Essington, which has had few ariid species recorded. The southern Gulf of Carpentaria and Gulf of Papua share several speciose families with Darwin Harbour (Carangidae, Leiognathidae, Apogonidae); many of these species are inhabitants of more turbid or estuarine waters. The Harbour has least in common with the commercial trawl ground fish fauna of coastal Queensland (the most speciose family for this habitat being the Scorpaenidae).

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HARD CORALS OF THE DARWIN REGION, NORTHERN TERRITORY, AUSTRALIA.

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ABSTRACT

A species list of hard corals recorded in subtidal and reef flat habitats of the Darwin region is presented. This is the first published list of the species of corals from the Darwin area, with a total of 125 scleractinian and non-scleractinian calcareous coral species belonging to 17 families and 47 genera, including one hydrozoan and one octocoral. The Faviidae is the family represented by the highest number of genera and species while relatively high numbers of species from the families Acroporidae and Poritidae are also present in the Darwin region. Similar numbers of species are recorded from the reef flat and the subtidal zone. Fewer species, but similar proportions of all major genera, are recorded from each family in Darwin compared with the east and west coasts of Australia.

KEYWORDS: Corals, Australia, Darwin, Cnidaria, check list.

INTRODUCTION

Darwin Harbour is a relatively shallow tropical estuarine system which is naturally turbid with a high rate of sedimentation and a large diurnal tidal amplitude of 8 m maximum spring tidal range (Michie 1987). The high levels of suspended sediment in Darwin Harbour are derived from wet season runoff, and wind and wave resuspension (Wrigley *et al.* 1990). The major coral beds in this region are sparsely distributed across the extensive intertidal reef flats, to a depth of 10 metres within the Harbour, and to greater depths in subtidal regions outside the Harbour (Hooper 1987). The increasing depth of the distribution of corals is probably related to the increasing depth of the photic zone as water moves through the middle Harbour to the ocean (Wrigley *et al.* 1990). The distribution of deep water hermatypic corals is restricted by the low levels of light penetration through the turbid waters (Hooper 1987). The substratum of habitats in which corals live is composed of dead coral, calcareous sand with clasts of coral rubble, and some terrestrially derived mud (Michie 1987). Very few nearshore reefs have been investigated biologically in north-west Australia (Hooper 1987). The only published estimate of the number of coral species occurring in Darwin Harbour records 30 species of hard corals from Channel Island to Lee Point (Low Choy 1983 in Hooper 1987).

The aim of this study was to prepare a checklist of the hard corals present in Darwin Harbour in preparation for a handbook which will provide full descriptions of the species that occur in the region.

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MATERIALS AND METHODS

The list of species presented in this paper is based on corals collected in subtidal and reef flat habitats in or near Darwin Harbour. The Harbour refers to all sites within Port Darwin, and extends from West Point to Lee Point. Collection sites are listed for each sample in the species list (see Results) and locations of sites are indicated by triangles in Figure 1. Two sites north of the Harbour, North West Vernon Island and the reef off Gunn Point Beach, were also sampled. Subtidal corals were collected during ten dives conducted during the Sixth International Marine Biological Workshop, in Darwin, in July 1993. Dive sites were chosen to sample the full range of coral habitats in the Darwin region, to maximise the number of species collected. The majority of specimens collected on reef flats were sampled during extensive surveys at extreme low tides in November/ December 1982. All corals collected were photographed prior to their removal, with the exception of the fungiid *Heliofungia actiniformis*, which was photographed but not collected.

Specimens were identified, using Veron and Pichon (1976, 1980, 1982), Veron 1985, Veron 1986, Veron, *et al.* (1977), Veron and Wallace (1984), Hoeksema (1989), Koh and Chou (1989), Lamberts (1982), Nemenzo (1981) and Veron (1990). Specimens which are apparently a distinct species but are not described in these references are listed as *Porites* sp. 1, *Montipora* sp. 1, *Montipora* sp. 2, *Montipora* sp. 3 and *Acropora* sp. 1. Specimens which were unidentifiable to species are listed using the genus, *e.g. Millepora* sp.

All samples are lodged at the Museum and Art Gallery of the Northern Territory (NTM), Darwin (registration numbers prefixed NTM C) or at the Museum of Tropical Queensland (MTQ), Townsville (registration numbers prefixed QM G). Collectors, habitat, and registration details for the specimens are listed in Table 1. Thirty-six specimens are lodged at MTQ with ten specimens being portions of specimens lodged at NTM. For specimens lodged in both museums, both registration numbers are listed in the Results section and the collection details listed in Table 1, corresponding to the NTM registration number.

RESULTS

As a result of the field surveys of the hard corals of the Darwin region, we found 123 species from 45 genera and 15 families of scleractinian corals, one hydrozoan, *Millepora* sp. and the octocoral *Tubipora musica*. This record includes all common species and many less common species, although it is unlikely that the list is exhaustive because some rarer species may have been overlooked or not present at the sites surveyed. The full species list, including museum registration numbers of each specimen and collection sites is given below.

DESCRIPTION OF CORAL HABITATS IN THE DARWIN REGION

The intertidal and subtidal substrata around Darwin on which corals are living mainly consist of rocks, unconsolidated and consolidated rubble, sand and mud. The intertidal reef flats are a mixture of low profile, silty, aggregations or rock and coral rubble, and elevated rock platforms with pools and lagoons that never dry. Dudley Point was the most extensively surveyed intertidal region. The coral cover here is noticeably richer on the outer parts of the reef and in the shallow channel between the reef and the headland. The dry areas are dominated by large *Symphyllia* heads and numerous faviids. Although some colonies of *Acropora* are often exposed, most occur in the rock pools and the channel, as do corals of many other genera such as *Porites*, *Goniopora* and *Turbinaria*. The latter is most common in the areas that are only uncovered at the lowest tides, on the reef margins and the channel entrance.

The substratum at the dive sites within the Harbour carried the highest sediment loads and had less rubble or other solid substratum. Large colonies of *Symphyllia* and medium to large colonies of faviids were the dominant coral types at the dive sites within the Harbour, except at Weed Reef where corals were sparse and the substratum very silty. From East Point to Lee Point, the water was somewhat clearer and the substratum less muddy, compared with more southerly study sites within the Harbour. Large colonies of *Porites*, *Symphyllia* and *Galaxea* (to 4 m diameter) were seen at the dive sites at Lee

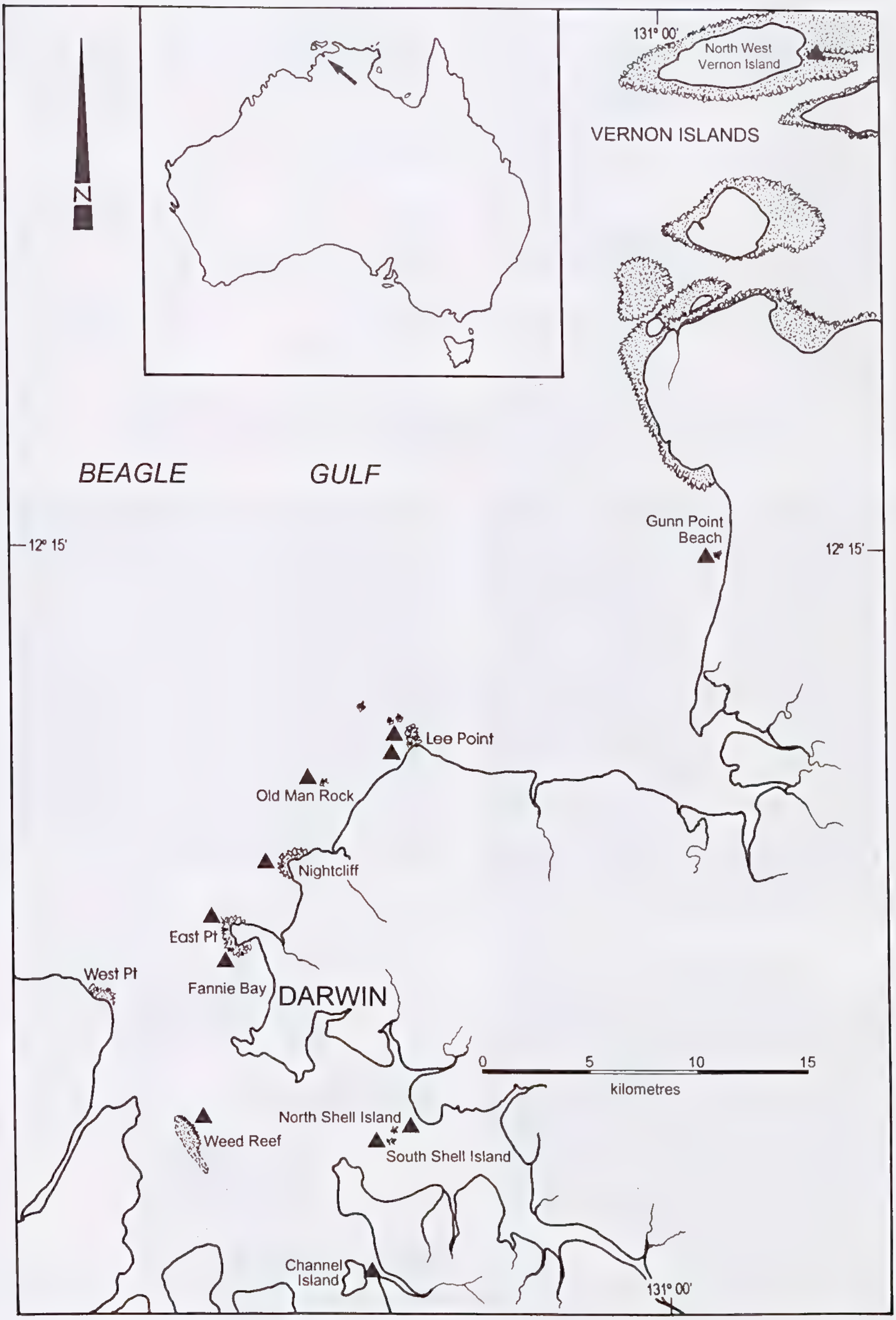

Fig. 1. Collection sites.

Table 1: Registration details of specimens recorded in this paper.

Registration number	Habitat	Collectors[1]	Identification[1]
NTM C3084-3085	Subtidal	PA	PA
NTM C5409	Reef flat	PA	PA
NTM C5423-5424			
NTM C6000-6071	Reef flat	PA, ZD, PH	ZD
NTM C6073-6183			
NTM C6244-6252			
NTM C6948-6949			
NTM C6072	Subtidal	PA	ZD
NTM C6945	Subtidal	PA	BH
NTM C7795-7808	Subtidal	JW	JW
NTM C7819-7959			
NTM C7809	Reef Flat	PA, SH	JW
NTM C7811			
NTM C7814-7817			
NTM C11973	Reef Flat	PA	PA
QM G specimens	Subtidal	JW	JW

[1] PA: P. Alderslade, ZD: Z. Dinesen, BH: B. Hoeksema, PH: P. Horner, SH: S. Horner, JW: J. Wolstenholme.

Point, Old Man Rock and Nightcliff. The highest diversity of coral species for Darwin Harbour appeared to be at the latter two sites, with smaller colonies of most other families being present between the large colonies. East Point differed from all other dive sites in having less suspended sediment in the water column and less sediment coating the substratum. No large colonies were present at East Point, with *Turbinaria* being the most common genus growing amongst many colonies of the sea whip *Junceella fragilis*. Arborescent and corymbose species of *Acropora* were the most common corals at the North West Vernon Island site. This site was also silty, with the substratum consisting largely of rubble of *Acropora* branches coated in a film of sediment.

DISTRIBUTION

Table 2 is compiled from two independent collections of the intertidal and subtidal zones. The presence of all species seen was recorded for each zone. Colonies of *Symphyllia* in the subtidal zone and possibly some rarer species in both zones may have been undersampled due to time constraints. Further surveys may show that some rarer species only recorded in one zone may occur in both environments.

Hard corals were found to be present across the reef flats and to a depth of 8 m (low water neap). A slightly greater number of species was recorded subtidally (87 species) than intertidally (79 species) (Table 2). The genus contributing most to these differences is *Montipora*, with two species occurring in the intertidal zone and an additional eight species occurring subtidally. A total of 53 species was recorded intertidally and subtidally. Species from most families were recorded in both zones. However, the families Milleporidae (*Millepora* sp.), Astrocoeniidae (*Stylocoeniella guentheri*) and Agariciidae (*Pachyseris speciosa*) were only found in the intertidal zone and were only represented by one species each. These species may also be present subtidally but were either absent or rare at the sites surveyed in this project.

SPECIES LIST

Class Hydrozoa
Order Milleporina
Family Milleporidae

***Millepora* sp.**
NTM C11973 (Dudley Pt).

Class Anthozoa
Order Alcyonacea
Family Tubiporidae

***Tubipora musica* Linnaeus, 1758**
NTM C5409, NTM C5423, NTM C5424 (Lee Pt); NTM C7805 (Channel I.).

Table 2 (continued). The species recorded from the reef flat and subtidal environments

	Intertidal	Subtidal
Family Pectiniidae (cont.)		
Mycedium elephantotus	*	*
Pectinia paeonia	*	*
Family Caryophylliidae		
Euphyllia glabrescens	*	*
Euphyllia paraancora	*	*
Family Dendrophylliidae		
Turbinaria peltata	*	*
Turbinaria patula		*
Turbinaria mesenterina	*	*
Turbinaria reniformis		*
Turbinaria stellulata	*	*
Turbinaria cf. *bifrons*		*
Turbinaria cf. *conspicua*	*	
Duncanopsammia axifuga	*	*
Family Poritidae		
Porites lobata	*	*
Porites australiensis	*	*
Porites mayeri		*
Porites cylindrica	*	*
Porites annae	*	
Porites sp. 1	*	*
Goniopora lobata		*
Goniopora somaliensis	*	*
Goniopora minor	*	
Goniopora palmensis	*	*
Goniopora stutchburyi	*	*
Goniopora cf. *calicularis*		*
Family Caryophylliidae (cont)		
Alveopora verrilliana	*	
Alveopora spongiosa	*	
Family Acroporidae		
Montipora hoffmeisteri		*
Montipora mollis	*	
Montipora turtlensis	*	
Montipora spongodes		*
Montipora spumosa		*
Montipora grisea		*
Montipora stellata		*
Montipora aequituberculata		*
Montipora sp. 1		*
Montipora sp. 2		*
Montipora sp. 3		*
Acropora brueggemanni	*	*
Acropora digitifera	*	*
Acropora robusta	*	*
Acropora nobilis		*
Acropora cf. *formosa*	*	*
Acropora millepora	*	*
Acropora tenuis		*
Acropora donei		*
Acropora nasuta	*	
Acropora valida		*
Acropora solitaryensis	*	
Acropora cf. *wallaceae*	*	*
Acropora sp. 1	*	*
Astreopora cucullata		*

Order Scleractinia
Family Thamnasteriidae

***Psammocora contigua* (Esper, 1797)**
NTM C6158 (Dudley Pt); NTM C7803 (Channel I.); NTM C7804 (NW Vernon I.); NTM C7811/QM G48138 (Gunn Pt).

***Psammocora superficialis* Gardiner, 1898**
NTM C7822 (Old Man Rock), NTM C7823 (East Pt).

***Psammocora profundacella* Gardiner, 1898**
NTM C6041 (Dudley Pt); NTM C7824 (South Shell I.).

Family Astrocoeniidae

***Stylocoeniella guentheri* Bassett-Smith, 1890**
NTM C6153 (Dudley Pt).

Family Pocilloporidae

***Pocillopora damicornis* Linnaeus, 1758**
NTM C7961 (Dudley Pt).

***Stylophora pistillata* Esper, 1797**
NTM C7819 (Nightcliff); NTM C7820 (NW Vernon I.); NTM C7821 (South Shell I.); NTM C7960 (Dudley Pt).

Family Faviidae

***Favia stelligera* (Dana, 1846)**
NTM C6096 (Dudley Pt).

***Favia favus* (Forskål, 1775)**
NTM C6053, NTM C6059 (Vesteys Beach); NTM C6104, NTM C6105, NTM C6112, NTM C6114 (Dudley Pt); NTM C7904 (Channel I.)

Favia pallida **(Dana, 1846)**
NTM C6009, NTM C6013, NTM C6014, NTM C6113 (Dudley Pt); NTM C7902 (Nightcliff).

Favia speciosa **(Dana, 1846)**
NTM C6017, NTM C6050, NTM C6101, NTM C6102, NTM C6103 (Dudley Pt); NTM C7903 (Channel I.).

Favia matthaii **Vaughan, 1918**
NTM C6015 (Dudley Pt).

Favia maritima **(Nemenzo, 1971)**
NTM C7905 (Lee Pt).

Barabattoia amicorum **(Edwards and Haime, 1850)**
NTM C6111 (Dudley Pt), NTM C7906 (NW Vernon Is), NTM C7907 (Weed Reef)

Favites chinensis **(Verrill, 1866)**
NTM C7911 (Channel I.).

Favites abdita **(Ellis and Solander, 1786)**
NTM C6057 (Vesteys Beach).

Favites halicora **(Ehrenberg, 1834)**
NTM C7908 (East Pt).

Favites flexuosa **(Dana, 1846)**
NTM C6012, NTM C6016 (Dudley Pt); NTM C7909 (Old Man Rock); NTM C7910 (Weed Reef).

Favites complanata **(Ehrenberg, 1834)**
NTM C6130 (Dudley Pt).

Favites pentagona **(Esper, 1794)**
NTM C6007, NTM C6027, NTM C6033, NTM C6035, NTM C6080, NTM C6081, NTM C6089, NTM C6095, NTM C6122, NTM C6123, NTM C6124 (Dudley Pt); NTM C7912 (Old Man Rock); NTM C7913 (Lee Pt); NTM C7914 (East Pt).

Favites **sp.**
NTM C6004, NTM C6028 (Dudley Pt).

Goniastrea retiformis **(Lamarck, 1816)**
NTM C6018, NTM C6127, NTM C6128, NTM C6129 (Dudley Pt).

Goniastrea aspera **(Verrill, 1865)**
NTM C6131, NTM C6132, NTM C6133, NTM C6134, NTM C6136 (Dudley Pt); NTM C7915 (North Shell Is); NTM C7916 (Channel I.).

Goniastrea pectinata **(Ehrenberg, 1834)**
NTM C6119, NTM C6120, NTM C6121 (Dudley Pt); NTM C7917 (Nightcliff).

Goniastrea **sp.**
NTM C7918 (Old Man Rock).

Platygyra daedalea **(Ellis and Solander, 1786)**
NTM C6038, NTM C6135, NTM C6137, NTM C6138, NTM C6139, NTM C6140, NTM C6141, NTM C6142, NTM C6143, NTM C6144, NTM C6145 (Dudley Pt); NTM C7919, NTM C7920, NTM C7921 (Channel I.); NTM C7922 (Weed Reef); NTM C7923 (South Shell I.).

Platygyra **c.f.** ***daedalea*** **(Ellis and Solander, 1786)**
NTM C7924 (Channel I.).

Platygyra lamellina **(Ehrenberg, 1834)**
NTM C79225 (Lee Pt).

Platygyra sinensis **(Edwards and Haime, 1849a)**
NTM C6005, NTM C6024, NTM C6075, NTM C6076, NTM C6077 (Dudley Pt); NTM C7926 (North Shell I.); NTM C7927 (Channel I.).

Platygyra verweyi **Wijsman-Best, 1976**
NTM C6092, NTM C6094 (Dudley Pt).

Leptoria phrygia **(Ellis and Solander, 1786)**
NTM C6047, NTM C6090 (Dudley Pt).

Hydnophora exesa **(Pallas, 1766)**
NTM C6088, NTM C6093 (Dudley Pt); NTM C7898 (Lee Pt); NTM C7899 (East Pt); NTM C7900 (Nightcliff).

Montastrea curta **(Dana, 1846)**
NTM C7928 (Lee Pt).

Montastrea annuligera **(Edwards and Haime, 1849a)**
NTM C7929 (Old Man Rock).

Montastrea valenciennesi **(Edwards and Haime, 1848a)**
NTM C6040, NTM C6100 (Dudley Pt); NTM C7930 (Old Man Rock); NTM C7931 (East Pt); NTM C7932 (Nightcliff).

Plesiastrea versipora **(Lamarck, 1816)**
NTM C6049, NTM C6073, NTM C6074 (Dudley Pt).

Leptastrea purpurea **(Dana, 1846)**
NTM C6021, NTM C6037, NTM C6082, NTM C6083 (Dudley Pt).

Leptastrea transversa **Klunzinger, 1879**
NTM C7933 (NW Vernon I.).

Cyphastrea serailia **(Forskål, 1775)**
NTM C7934 (Old Man Rock); NTM C7935, NTM C7936 (East Pt).

Cyphastrea chalcidicum **(Forskål, 1775).**
NTM C6025, NTM C6043, NTM C6098 (Dudley Pt).
Cyphastrea microphthalma **(Lamarck, 1816)**
NTM C6086, NTM C6087, NTM C6091 (Dudley Pt); NTM C7937 (Old Man Rock).

Moseleya latistellata **Quelch, 1884**
NTM C6072 (NW Vernon I.); NTM C6107, NTM C6108 (Dudley Pt); NTM C7938 (Channel I.).

Family Agariciidae

Pachyseris speciosa **(Dana, 1846)**
NTM C6036 (Dudley Pt).

Family Siderastreidae

Pseudosiderastrea tayamai **Yabe and Sugiyama, 1935**
NTM C6058 (Vesteys Beach); NTM C6151 (Dudley Pt); NTM C7866 (Weed Reef).

Coscinaraea columna **(Dana, 1846)**
NTM C7867 (Lee Pt); NTM C7868 (Nightcliff).

Family Fungiidae

Heliofungia actiniformis **(Quoy and Gaimard, 1833)**
NTM C6945 (NW Vernon I.).

Fungia fungites **(Linnaeus, 1758)**
NTM C6948 (Vesteys Beach); NTM C6949 (Dudley Pt); NTM C7869, NTM C7870, NTM C7872, NTM C7873 (NW Vernon I.), NTM C7871 (South Shell I.).

Herpolitha limax **(Esper, 1797)**
NTM C6154 (Dudley Pt); NTM C7874 (North Shell I.).

Polyphyllia talpina **(Lamarck, 1801)**
NTM C6160 (Dudley Pt); NTM C7875 (Lee Pt); NTM C7876 (NW Vernon I.).

Lithophyllon undulatum **Rehberg, 1892**
NTM C6045 (Dudley Pt); NTM C7877 (Nightcliff); NTM C7878, NTM C7879 (Weed Reef).

Podabacia crustacea **(Pallas, 1766)**
NTM C6156 (Dudley Pt); NTM C7816 (Gunn Pt); NTM C7880 (Old Man Rock); NTM C7881 (Weed Reef).

Family Oculinidae

Galaxea astreata **(Lamarck, 1816)**
NTM C7796 (Nightcliff).
Galaxea **c.f.** ***astreata*** **(Lamarck, 1816)**
NTM C6078, NTM C6079 (Dudley Pt); NTM C7801 (Old Man Rock).

Galaxea fascicularis **(Linnaeus, 1767)**
NTM C6084, NTM C6085 (Dudley Pt); NTM C7798 (Weed Reef)

Galaxea **c.f.** ***fascicularis*** **(Linnaeus, 1767).**
NTM C7799 (Weed Reef), NTM C7800 (Old Man Rock).

Archohelia rediviva **Wells and Alderslade, 1979**
NTM C3084 (South Shell I.); NTM C7802 (East Pt).

Family Merulinidae

Merulina ampliata **(Ellis and Solander, 1786)**
NTM C6106 (Dudley Pt); NTM C7901 (Nightcliff).

Family Mussidae

Cynarina lacrymalis **(Edwards and Haime, 1848c)**
NTM C7806 (North Shell I.); NTM C7807, NTM C7808 (Weed Reef).

Acanthastrea echinata **(Dana, 1846)**
NTM C6097, NTM C6099 (Dudley Pt); NTM C7891 (Old Man Rock).

Acanthastrea hillae **Wells, 1955**
NTM C7892 (Old Man Rock); NTM C7893 (Lee Pt).

Acanthastrea **sp.**
NTM C7894 (Lee Pt).

Lobophyllia hemprichii **(Ehrenberg, 1834)**
NTM C6110, NTM C6115, NTM C6116, NTM C6117 (Dudley Pt); NTM C7895 (Channel I.); NTM C7896 (Weed Reef).

Symphyllia recta **(Dana, 1846)**
NTM C6003, NTM C6118 (Dudley Pt); NTM C7897 (Lee Pt).

Symphyllia radians **Edwards and Haime, 1849b**
NTM C6109 (Dudley Pt).

Symphyllia agaricia **Edwards and Haime, 1849b**
NTM C6055 (Vesteys Beach).

Family Pectiniidae

Echinophyllia aspera **(Ellis and Solander, 1786)**
NTM C6175, NTM C6176, NTM C6177, NTM C6178 (Dudley Pt); NTM C7882, NTM C7884 (Nightcliff); NTM C7883 (South Shell I.).

Oxypora lacera **(Verrill, 1864)**
NTM C6048 (Dudley Pt).

Mycedium elephantotus **(Pallas, 1766)**
NTM C6173, NTM C6174 (Dudley Pt); NTM C7885 (North Shell I.); NTM C7886, NTM C7888 (Nightcliff); NTM C7887 (South Shell I.).

Pectinia paeonia **(Dana, 1846)**
NTM C6031 (Dudley Pt); NTM C7889 (Weed Reef); NTM C7890 (NW Vernon I.).

Family Caryophylliidae

Euphyllia glabrescens **(Chamisso and Eysenhardt, 1821)**
NTM C6183 (Dudley Pt); NTM C7939 (Lee Pt); NTM C7940 (South Shell I.).

Euphyllia paraancora **Veron, 1990**
NTM C3085 (NW Vernon I.); NTM C6152, NTM C6182 (Dudley Pt); NTM C7941 (Lee Pt); NTM C7942 (Nightcliff).

Family Dendrophylliidae

Turbinaria peltata **(Esper, 1794)**
NTM C6171, NTM C6172 (Dudley Pt); NTM C7943 (Lee Pt).

Turbinaria patula **(Dana, 1846)**
NTM C7944 (Lee Pt); NTM C7945 (Old Man Rock).

Turbinaria mesenterina **(Lamarck, 1816)**
NTM C6006, NTM C6052 (Dudley Pt); NTM C7946 (South Shell I.); NTM C7947, NTM C7948 (Old Man Rock).

Turbinaria reniformis **Bernard, 1896**
NTM C7949 (North Shell I.).

Turbinaria stellulata **(Lamarck, 1816)**
NTM C6044 (Dudley Pt), NTM C7797 (Lee Pt).
Turbinaria **c.f.** ***bifrons*** **Bruggemann, 1877**
NTM C7795 (Nightcliff).

Turbinaria **c.f.** ***conspicua*** **Bernard, 1896**
NTM C6026 (Dudley Pt).

Turbinaria **sp.**
NTM C6179, NTM C6180 (Dudley Pt).

Duncanopsammia axifuga **(Edwards and Haime, 1848b)**
NTM C6159 (Dudley Pt); NTM C7951 (East Pt).

Family Poritidae

Porites lobata **Dana, 1846**
NTM C6030, NTM C6051, NTM C6148 (Dudley Pt); NTM C7839 (East Pt); NTM C7840 (North Shell I.).

Porites australiensis **Vaughan, 1918**
NTM C6008 (Dudley Pt); NTM C7841, NTM C7842 (Old Man Rock); NTM C7843 (Nightcliff).

Porites mayeri **Vaughan, 1918**
NTM C7844 (Channel I.); NTM C7845 (Old Man Rock).

Porites cylindrica **Dana, 1846**
NTM C6010, NTM C6019 (Dudley Pt); NTM C7846 (NW Vernon I.); NTM C7847 (North Shell I.).

Porites annae **Crossland, 1952**
NTM C6149, NTM C6150, NTM C6155 (Dudley Pt).

Porites **sp. 1**
NTM C6000, NTM C6054, NTM C6146, NTM C6147 (Dudley Pt); NTM C7848, NTM C7850 (Nightcliff); NTM C7849 (NW Vernon I.).

Goniopora lobata **Edwards and Haime, 1860**
NTM C7851, NTM C7853, NTM C7854 (Lee Pt); NTM C7852, NTM C7855, NTM C7856 (Channel I.); NTM C7857 (North Shell I.); NTM C7858 (Weed Reef).

Goniopora somaliensis **Vaughan, 1907**
NTM C6066, NTM C6067 (Dudley Pt); NTM C7859 (East Pt).

Goniopora minor **Crossland, 1952**
NTM C6065, NTM C6069 (Dudley Pt).

Goniopora palmensis **Veron and Pichon, 1982**
NTM C6002, NTM C6060, NTM C6064 (Dudley Pt); NTM C7860 (Weed Reef).

Goniopora stutchburyi **Wells, 1955**
NTM C6056, NTM C6157 (Vesteys Beach); NTM C7861 (East Pt); NTM C7862 (North Shell I.).

Goniopora **c.f.** ***calicularis*** **(Lamarck, 1816)**
NTM C7863 (Nightcliff).

Alveopora verrilliana **Dana, 1872**
NTM C6042, NTM C6063 (Dudley Pt).

***Alveopora spongiosa* Dana, 1846**
NTM C6039, NTM C6068 (Dudley Pt).

***Alveopora* sp.**
NTM C7864 (Old Man Rock); NTM C7865 (Weed Reef).

Family Acroporidae

***Montipora hoffmeisteri* Wells, 1954**
NTM C7825 (Lee Pt).

***Montipora mollis* Bernard, 1897**
NTM C6001, NTM C6011, NTM C6020, NTM C6022, NTM C6029, NTM C6046, NTM C6070, NTM C6125, NTM C6126 (Dudley Pt).

***Montipora turtlensis* Veron and Wallace, 1984**
NTM C6034 (Dudley Pt).

***Montipora spongodes* Bernard, 1897**
NTM C7826 (North Shell I.).

***Montipora spumosa* (Lamarck, 1816)**
NTM C7827 (Nightcliff); NTM C7828 (NW Vernon I.).

***Montipora grisea* Bernard, 1897**
NTM C7829 (Old Man Rock); NTM C7830 (East Pt).

***Montipora stellata* Bernard, 1897**
NTM C7831 (NW Vernon I.)

***Montipora aequituberculata* Bernard, 1897**
NTM C7817 (Gunn Pt); NTM C7832 (NW Vernon I.).

***Montipora* sp. 1**
NTM C7833 (Weed Reef).

***Montipora* sp. 2**
NTM C7834, NTM C7836 (North Shell I.); NTM C7835 (Old Man Rock)

***Montipora* sp. 3**
NTM C7837 (Lee Pt).

***Acropora brueggemanni* (Brook, 1893)**
NTM C6164, NTM C6165, NTM C6166, NTM C6246/QM G48118 (Dudley Pt); QM G46240 (NW Vernon I.); QM G48119 (Channel I.).

***Acropora digitifera* (Dana, 1846)**
NTM C6170 (Dudley Pt); NTM C7950/QM G48120 (NW Vernon I.).

***Acropora robusta* (Dana, 1846)**
NTM C6250 (Dudley Pt); QM G48101 (Nightcliff).

***Acropora nobilis* (Dana, 1846)**
NTM C6251 (Dudley Pt); NTM C7952, QM G48108, QM G48109 (NW Vernon I.); QM G48105, QM G48106 (Nightcliff); QM G48107 (Channel I.); QM G48110 (South Shell I.).

***Acropora* c.f. *formosa* (Dana, 1846)**
NTM C7815(Gunn Pt); QM G48102 (Weed Reef); QM G48103 (North Shell Is); QM G48104 (Nightcliff).

***Acropora millepora* (Ehrenberg, 1834)**
NTM C6169, NTM C6245 (Dudley Pt); NTM C7953, QM G48128 (NW Vernon I.)

***Acropora* c.f. *millepora* (Ehrenberg, 1834)**
NTM C7954/QM G48124 (NW Vernon I.).

***Acropora tenuis* (Dana, 1846)**
NTM C7955/QM G48127 (NW Vernon I.)

***Acropora donei* Veron and Wallace, 1984**
NTM C7956(NW Vernon Is); QM G48129 (Nightcliff).

***Acropora* c.f. *donei* Veron and Wallace, 1984**
NTM C7957/QM G48130 (South Shell I.); NTM C7958/QM G48126 (NW Vernon I.).

***Acropora nasuta* (Dana, 1846).**
NTM C6244 (Dudley Pt).

***Acropora valida* (Dana, 1846)**
NTM C7959, QM G48125 (NW Vernon I.)

***Acropora solitaryensis* Veron and Wallace, 1984**
NTM C7809/QM G48137 (West Pt).

***Acropora* c.f. *wallaceae* Veron, 1990**
NTM C6161, NTM C6162/QM G48117, NTM C6163 (Dudley Pt); QM G48111, QM G48112, QM G48113 (South Shell I.); QM G48114, QM G48115 (Nightcliff); QM G48116 (Channel I.).

***Acropora* sp. 1**
NTM C6167, NTM C6168, NTM C6248, NTM C6249 (Dudley Pt); NTM C7814/QM G48136(Gunn Pt); QM G48131, QM G48132 (Nightcliff); QM G48133 (NW Vernon I.); QM G48134 (Weed Reef).

***Acropora* c.f. sp. 1**
NTM C6252 (Dudley Pt).

***Acropora* sp.**
NTM C6247/QM G48135 (Dudley Pt).

***Astreopora cucullata* Lamberts, 1980**
NTM C7838 (Lee Pt).

DISCUSSION

A total of 123 species from 45 genera and 15 families of scleractinian corals is recorded from Darwin Harbour and nearby areas. One hydrozoan species, *Millepora* sp., and the octocoral *Tubipora musica* were also recorded. All except four species were recorded within the Harbour. These four species *Leptastrea transversa*, *Montipora aequituberculata*, *Acropora tenuis* and *Acropora valida* were only recorded from Gunn Point or North West Vernon Island. Although there are no extensive reef systems developed in the areas explored during this study, there is a high species diversity with significantly more species recorded than the previous estimate of 30 species of hard corals from Channel Island to Lee Point.

Distribution: intertidal vs subtidal. Hard corals were found to occur across the reef flats and to a depth of 8 m, which is consistent with (previous work by) Hooper (1987) who reported that the distribution of corals of the Darwin region is between 2 to 10 m depth. In this survey, a slightly greater number of species were found subtidally (87 species) compared with the reef flats (79 species) (Table 2). Intertidal surveys, were conducted during low spring tides and thus included samples from the interface of the intertidal and subtidal zones. This may explain the higher proportion of species recorded intertidally.

Distribution: a comparison with the east and west Australian coasts. The numbers of genera and species in each family of hard corals recorded from the Darwin region, are compared to the same families for the east and west coasts of Australia in Table 3. Records from the east Australian coast include collections from the Great Barrier Reef south to the Solitary Islands on the coast, as well as Chesterfield Atoll, Elizabeth and Middleton Reefs, and Lord Howe Island, (see Veron and Wallace 1984). Records from the West Australian coast include collections from the Kimberley coast to Recherche Archipelago, as well as Ashmore Reef, Cartier Island, Seringapatam Reef, Scott Reef, and Rowley Shoals (Veron and Marsh 1988).

Species from all scleractinian families described from the east and west coasts of Australia (Veron and Pichon 1976; Veron and Pichon 1980; Veron and Pichon 1982; Veron *et al.* 1977; Veron and Wallace 1984 and Veron and Marsh 1988) are found in Darwin, with the exception of the monospecific family Trachyphylliidae. In terms of number of species and genera, the largest family in the Darwin region, is the Faviidae, consisting of 32 species from 12 genera (Table 3). The Faviidae also has the largest number of genera on the east and the west coasts of Australia (17 genera). The largest number of species on the east and west coasts however, occurs within the Acroporidae with 117 species on the east coast and 101 species on the west. Although the number of species is relatively high, substantially fewer species of Acroporidae, were recorded from the Darwin region compared with the records for the east and west Australian coasts. This is probably due to the turbid conditions of the Darwin region, which are not preferred by many species of *Acropora*.

The Poritidae is represented by relatively high numbers of species (35 species on the east coast, 14 species around Darwin and 36 species from the west coast) from a small number of genera (four genera from east Australia and three genera from Darwin and the west coast) in all three regions. The numbers of Fungiidae around Darwin contrast with those recorded for the east and west coasts, the most notable difference being that there was only one species of *Fungia* found compared with 15 species recorded on the east coast of Australia and 12 species on the west coast (Table 3). A second species of *Fungia* (*F. repanda*) has also been recorded from Darwin (B. Hoeksema, pers. comm.). The reason that so few species of *Fungia* have been found in the Darwin region, compared with the east and west coasts of Australia, is unknown. *Cynarina* is the only genus recorded in Darwin that is not recorded from west Australia, while all Darwin genera are recorded from east Australian reefs.

Pocillopora damicornis is extremely rare in the Darwin region (P. Alderslade, personal observation). This is noteworthy because this species is common on both east (Veron and Pichon 1976) and west (Veron and Marsh 1988) Australian reefs, and reefs in the Indian and Pacific Oceans (Richmond 1985). There are a number of factors, relating to environmental conditions, which could explain the paucity of *Pocillopora damicornis* in the Darwin region. This species has been recorded to bleach frequently and severely at Magnetic Island, Townsville (Oliver 1985) possibly indicating that this species is not

Table 3. Number of species and genera of corals in the Darwin region compared with eastern and western Australia.

	Eastern Australia*			Darwin Harbour and N.W. Vernon Island			Western Australia*		
	#genera in family	#species in family	#species in genus	#genera in family	#species in family	#species in genus	#genera in family	#species in family	#species in genus
CLASS Hydrozoa									
ORDER Milleporina									
Family Milleporidae	1	?		1	?		1	?	
Millepora sp.			?			1			?
CLASS Anthozoa									
ORDER Stolonifera									
Family Tubiporidae	1	1		1	1		1	1	
Tubipora musica			1			1			1
ORDER Scleractinia									
Family Thamnasteriidae	1	7		1	3		1	9	
Psammocora			7			3			9
Family Astrocoeniidae	1	2		1	1		1	2	
Stylocoeniella			2			1			2
Family Pocilloporidae	5	9		2	2		4	9	
Pocillopora			4			1			5
Stylophora			1			1			1
Family Faviidae	17	54		12	32		17	57	
Favia			12			6			13
Barabattoia			1			1			1
Favites			9			6			8
Goniastrea			7			3			8
Platygyra			5			4			6
Leptoria			1			1			1
Hydnophora			3			1			4
Montastrea			4			3			4
Plesiastrea			1			1			1
Leptastrea			6			2			6
Cyphastrea			4			3			4
Moseleya			1			1			1
Family Trachyphylliidae	1	1		0	0		2	2	
Family Agariciidae	5	2		1	1		5	2	
Pachyseris			2			1			2
Family Siderastreidae	2	6		2	2		2	5	
Pseudosiderastrea			1			1			1
Coscinaraea			5			1			4
Family Fungiidae	11	21		6	6		9	18	
Heliofungia			1			1			1
Fungia			15			1			12
Herpolitha			2			1			2
Polyphyllia			1			1			1
Lithophyllon			1			1			1
Podabacia			1			1			1

Table 3 (continued). Number of species and genera of corals in the Darwin region compared with eastern and western Australia

	Eastern Australia*			Darwin Harbour and N.W. Vernon Island			Western Australia*		
	#genera in family	#species in family	#species in genus	#genera in family	#species in family	#species in genus	#genera in family	#species in family	#species in genus
Family Oculinidae	3	4		2	3		2	2	
Galaxea			2			2			2
Archohelia			1			1			-
Family Merulinidae	3	1		1	1		2	2	
Merulina			1			1			2
Family Mussidae	6	13		4	7		6	13	
Cynarina			1			1			0
Acanthastrea			4			2			4
Lobophyllia			4			1			4
Symphyllia			4			3			5
Family Pectiniidae	4	10		4	4		4	11	
Echinophyllia			4			1			3
Oxypora			2			1			2
Mycedium			1			1			2
Pectinia			3			1			4
Family Caryophylliidae	4	4		1	2		5	4	
Euphyllia			4			2			4
Family Dendrophylliidae	3	10		2	8		3	11	
Turbinaria			9			7			10
Duncanopsammia			1			1			1
Family Poritidae	4	35		3	14		3	36	
Porites			13			6			15
Goniopora			15			6			14
Alveopora			7			2			7
Family Acroporidae	4	117		3	25		4	101	
Montipora			36			11			35
Acropora			73			13			62
Astreopora			8			1			4

*East Australian records are taken from the AIMS monograph series for zooxanthellate scleractinian species; Veron (1986) for *Millepora* sp. (number of species unknown) and *Tubipora musica*; Wells and Alderslade (1979) for *Archohelia rediviva*. West Australian records are taken from Veron and Marsh (1988) for scleractinian species; Veron (1986) for *Millepora* sp. (number of species unknown) and *Tubipora musica*; no reference for *Archohelia rediviva*.

N.B. *Lithophyllon undulatum* was synonymised with *L.* cf *edwardsi* (Hoeksema, 1989), and *Turbinaria conspicua* was synonymised with *T. bifrons* (Veron and Pichon, 1980) and thus each of these pairs is recorded as one species in their respective tallies for the east Australian coast. Tallies include all species referred to as 'cf' and unnamed species (*e.g. Porites* sp 1). Specimens identified only to genus level are not counted.

a successful competitor under adverse conditions such as high turbidity.

The families Thamnasteriidae, Astrocoeniidae, Pocilloporidae, Agariciidae, Siderastreidae, Oculinidae, Merulinidae, Mussidae, Pectiniidae, Caryophylliidae and Dendrophylliidae are represented by relatively low numbers of genera and species for the three regions discussed and elsewhere in the Indo-Pacific region.

The only azooxanthellate coral recorded was *Archohelia rediviva*, which was found in both the intertidal and subtidal zones. The occurence of this species is significant because this is an uncommon species previously recorded from only three locations, all in Queensland on the east coast of Australia (Wells and Alderslade 1979; MTQ unpublished records). Azooxanthellate corals are normally found on steep walls, under ledges, in deep water or in other locations where light is limited. The azooxanthellate coral, *Tubastrea* sp., has been recorded from the wreck of the SS *Zealandia* in Darwin Harbour at a depth of 22 m (NTM records). It is likely that other species or genera of azooxanthellate corals are present on wrecks and other locations in the Darwin region with restricted light levels, but such habitats were not surveyed during this study.

The skeletal morphologies of species from most families are similar in appearance to the same species on the Great Barrier Reef. However, colonies of some species of *Acropora* collected in Darwin differ in skeletal morphology. For example, in *Acropora formosa* the axial corallites are larger relative to branch size compared with colonies on the Great Barrier Reef. Three tentative species of *Montipora* (*Montipora* sp. 1, 2 and 3) collected in Darwin, have very small corallites compared with the species of *Montipora* described from the Great Barrier Reef (B. Stobart pers. comm.). Further research is necessary to determine if they are different species from those from for the Great Barrier Reef (Veron and Wallace 1984) or morphological variants. Veron and Marsh (1988) also recorded several species of *Acropora* to have distinct variants several species in specific geographic regions, suggesting that they may be sibling species or geographic subspecies. More extensive surveys of the coral fauna, as well as studies of the morphological and genetic variation (DNA or electrophoretic studies) of the species in the Darwin region are necessary to confirm the taxonomic status of such colonies. It is possible that corals in the Darwin region may exhibit morphological variation compared with the same species on the Great Barrier Reef because they are breeding within a relatively isolated gene pool or as a result of environmental stress.

Major factors determining species diversity and abundance of corals between the intertidal and subtidal zones in the Darwin area and compared with the east and west coasts of Australia appear to be restricted light availability, turbidity, high levels of sedimentation, limited availability of suitable settlement substratum for coral larvae, and the limited range of habitats present.

Irradiance is probably one of the most important abiotic factors influencing coral reef development (Falkowski *et al.* 1990). Irradiance enables the photosynthetic endosymbiotic algae (zooxanthellae) to fix carbon which the coral then uses. Although quantitative data for light levels have not been published for Darwin Harbour, it is clear that the high levels of turbidity which often reduce visibility to 0.7 m (Hooper 1987) substantially reduce light levels reaching the corals in the waters of the region. Falkowski *et al.* (1990), using *Stylophora pistillata* as a study species, reported that corals living in shaded areas must obtain up to 60% of their carbon requirements from heterotrophic feeding, in contrast with corals growing under high light conditions which can obtain all their reduced carbon needs for animal respiration from photosynthesis by their zooxanthellae. Restricted light levels reaching the corals therefore influence their rate of growth by reducing rates of photosynthesis, and affect the depth to which corals can occur, and possibly also the species which are able to survive in the Darwin region. Light levels may also influence successful recruitment sites of coral larvae (Maida *et al.* 1994; Mundy 1994).

In addition to reducing the amount of light reaching the corals, high levels of turbidity also directly affect corals through sedimentation. Corals remove sediment from their colony surface through ciliary activities, mucous entanglement, polyp tissue expansion, and tentacular action (Hubbard and Pocock 1972; Stafford-Smith and Ormond 1992). This physical removal of sediment is an energy drain for the coral and thus reduces the amount of energy available for growth (Cortes and Risk 1985). Hubbard and Pocock (1972) and Stafford-Smith and Ormond (1992) also report that species with different colony and calyx morphologies differ in their ability to reject sediments. The strong tidal currents experienced in the Darwin region reduce the effects of sedimentation by physically removing the sediment from the surface of coral colonies (Rogers 1990), and this is possibly a factor in explaining the high number of species surviving in such a turbid environment.

High levels of sedimentation also affect recruitment of juvenile corals because coral larvae cannot successfully establish themselves in shifting sediments (Rogers 1990). Maida *et al.* (1994) and Rogers *et al.* (1984) suggest that the reduction or absence of coral recruitment on exposed settlement surfaces is due to sedimentation on these surfaces. Thus the films of sediment covering much of the bare substratum in Darwin Harbour may not be conducive to coral recruitment. Experimental evidence indicates that coral larvae preferentially settle in crevices (Wallace 1985; Harriott and Fisk 1987). Such crevices are likely to be filled with sediment and thus further reduce the availability of potential recruitment sites for coral spat.

Low variability in habitat types in the Darwin region is also a factor contributing to the smaller number of coral genera and species present, compared with the east and west Australian coasts. A major difference in the coral communities in the Darwin region is that there are no barrier reefs developed. A barrier reef system such as the Great Barrier Reef is a complex structure with many different types of habitats and biotic communities. These communities experience a range of different environmental parameters. The parameters include varying levels of wave energy, currents, light, nutrient supply, sedimentation and type of substratum (Done 1982; Rosen 1975) and are important in determining the types of coral communities and associated taxa found in a particular reef habitat or reef type. The diversity of the coral fauna in the Darwin region seems most comparable to that of the inner-shelf reefs of the GBR (Done 1982). These reefs are nearshore, silt-affected, and have relatively low diversity (Done 1982).

CONCLUSION

No clear trends are apparent in the numbers of species or genera occurring intertidally and subtidally in Darwin Harbour. All larger families and genera have species present in both zones. Although there are fewer species of hard corals in Darwin Harbour compared to the the east and west Australian coasts, the relative proportions of species in each genus and the number of species and genera in each family are similar to the east and west Australian coasts, with the exception of the Faviidae. Considering the high sediment load, strong tidal currents, and long periods of exposure for reef flat corals during low tides, the species diversity of Darwin Harbour is comparatively high. However, because of the limited range of habitat types, and therefore reduced potential for species diversity, it is not surprising that the diversity is lower than on the east and west coasts of Australia where barrier reefs with large ranges of habitat variability exist.

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HEAVY METALS IN SCLERACTINIAN CORALS AND MARINE SEDIMENTS FROM DARWIN HARBOUR, AUSTRALIA

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ABSTRACT

Corals are potentially useful biological monitors for heavy metals near Darwin Harbour because they are long-lived, sedentary, widespread, and numerous. Here, concentrations are obtained for Cd, Pb, Cu, Zn, Ni and Cr in tissues and skeletons of two coral species from the harbour precincts. Sediments are also analysed for heavy metals. Cu, Zn, Ni and Cr concentrate in fine sediment, indicating the importance of this fraction for analysis. Sequential extraction shows these metals are bound dominantly by phases resistant to mild solvents. Sodium acetate and acetic acid exposure, designed to mobilise carbonate bound metals, significantly released Pb, Cu and Ni. Heavy metals in Darwin Harbour sediments appear similar between sites where corals are sampled. Concentrations measured in coral tissues and skeletons are also consistent between sites, and between the two coral species. Consequently, baseline data is provided for future study of Darwin Harbour.

KEYWORDS: Darwin Harbour, baseline, heavy metals, sediment, corals, *Montastrea annuligera, Goniastrea aspera.*

INTRODUCTION

Darwin is a port city with little human habitation and industry relative to other Australian capital cities. In anticipation of future development of the city and harbour, the establishment of baseline data for heavy metal concentrations in the sediments of harbour precincts is important for future comparison. This allows better management of ecosystems which will be subject to increased human impact. Furthermore, public health issues are important because biota from the ecosystem are consumed by the general public. Methods for monitoring metal concentrations in water and sediment include the use of biological monitors such as molluscs (Peerzada and Dickinson 1988; Peerzada *et al.* 1990).

Corals have been suggested as biological monitors (Hanna 1989), since they are common in Darwin Harbour and accumulate heavy metals. Coral skeletons aggregate heavy metals by three mechanisms: a) direct adsorption onto dead carbonate surfaces (Kitano *et al.* 1976; Papadopoulos *et al.* 1988), b) inclusion of particulate material within the coral skeleton (St John 1973, 1974; Goreau 1977; Brown 1987) and c) substitution for calcium within the aragonite lattice (Dodge *et al.* 1984; Shen *et al.* 1987; 1988; Linn *et al.* 1989). The latter pathway is possibly influenced by skeletal proteins during skeletogenesis (Mitterer 1978). Coral tissue also accumulates heavy metals (Hanna and Muir 1990; McConchie and Harriott 1992), although Harland and Nganro (1990), and Harland *et al.* (1990) show that zooxanthellar activity and mucus secretion affect metal concentrations in coelenterates. This information collectively suggests that corals could be used as biological monitors in Darwin Harbour, although the ability of coral tissue to accumulate environmental metal loads requires better definition.

This study provides an assessment of Cd, Pb, Cu, Zn, Ni, and Cr bound firmly by coral tissue, and adsorbed onto the skeleton of two

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species of coral in the vicinity of Darwin Harbour. Marine sediments collected in association with corals are also analysed for reactive heavy metals, because they provide an accepted basis for determining environmental metal loads. These data are used to assess whether corals can be used as sentinel organisms for monitoring metal levels in this environment.

MATERIALS AND METHODS

Field collection and sample pretreatment. Two coral species are included in this study; *Montastrea annuligera* (Edwards and Haime) and *Goniastrea aspera* (Verrill). Corals and sediment were collected by scuba from the locations indicated in Figure 1, chosen on the basis of reported coral occurrence. At the start of each dive, surface sediment was scraped into an acid-rinsed 100 mL polyethylene vial, and a duplicate sample obtained at the end of the dive. The two coral species selected for analysis were chosen because they were well represented both within and between sites. Samples were chiselled from the outer rim of replicate colonies of brain corals to include surficial tissues, and transported to the field camp in a plastic collection tub filled with seawater. Upon return to the camp sediments were frozen. Coral samples were rinsed in 1L of distilled water, then dried for several days at 60±10°C, stored in polyethylene bags, andfrozen for transport to Southern Cross University for analysis.

Analysis of coral tissue. Thirty two *Montastrea annuligera* and *Goniastrea aspera* samples were randomly selected from separate colonies. Following trimming of the samples with a hacksaw to a size suitable for analysis, sawmarks were abraded from cut surfaces with silicon carbide on a glass lap, and the cut surfaces rinsed with a high pressure jet of Milli-Q water delivered from a water-pik to remove the abrasive.

Tissue loosened from the carbonate skeleton after 15 hours of decalcification with 0.2M

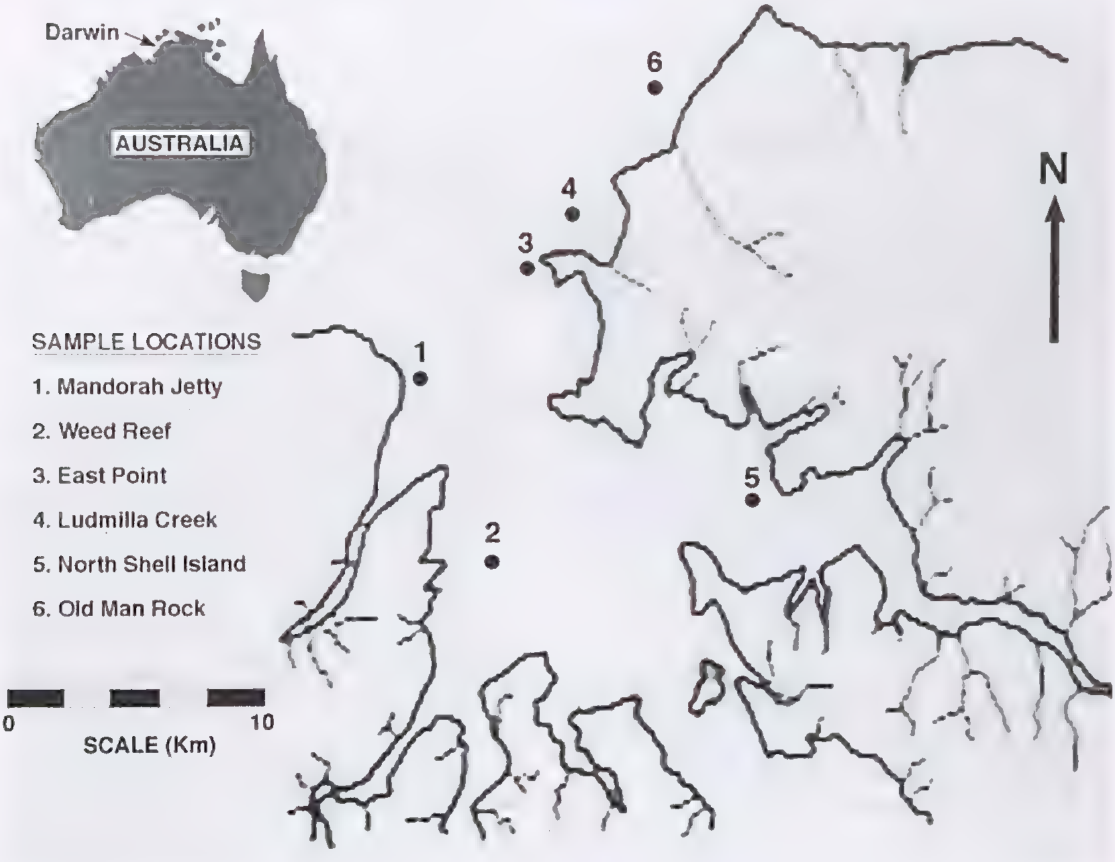

Fig. 1. Map of Darwin Harbour showing sample locations.

EDTA (Analar) were transferred into filter units (Millipore) with the water-pik, and settled by vacuum filtration onto tare weighed Whatman 41 filters. When filtration ceased due to clogging, excess supernatant was removed by syphoning with a 5 mL autopipette, and tissue weights were measured after oven drying the samples (tissue + filter paper) for 56 hours at 55°C. Samples were digested in 20 mL of boiling $HNO_3:H_2O_2$ (1:1 mixture, Analar), cooled, and filtered under vacuum through Whatman 41 filters. A subsequent 25 mL acid rinse (0.012M HCl Analar) was used to ensure complete recovery. Filtrates were returned to the glass beakers with a 5 mL acid rinse, volume reduced to <10 mL on a hotplate, and measured accurately to 10 mL for analysis.

Heavy metal concentrations were determined with a flame atomic adsorption spectrophotometer (GBC 903). Detection limits calculated by measuring the 3σ from twelve blanks are as follows (ppm): Cd = 0.03, Pb = 0.07, Cu = 0.06, Zn = 0.09, Ni = 0.37, Cr = 0.09. These represent values in 10 mL of sample digest, before recalculating to sample size. Standard addition was used for matrix correction.

Analysis of metals adsorbed onto coral skeleton. Twenty two samples were cut 5 cm directly below the rim of the colonies to represent recent coral growth. Samples were crushed to <5 mm in triple lined polyethylene bags with a porcelain pestle, and approximately 10 g of sample placed into 500 mL polycarbonate vials. Sieve-like perforations had been previously drilled into the vial caps to facilitate easy addition and removal of fluids as discussed below.

Organic phases were removed from the crushed skeleton using 30 mL of 30% H_2O_2 (Analar) buffered to a pH of 8.2 to prevent dissolution of the skeleton. Samples were kept at 20°C for 90 minutes, then at 70°C for 4 hours during digestion. The H_2O_2 was discarded, and the samples thoroughly rinsed with 100 mL of Milli-Q water.

Ammonium pyrrolidine dithiocarbamate (APDC) and sodium diethyldithiocarbamate (DETC) are two chelates often used for heavy metal analysis, because they select transition metals and not s-block metals. Thirty mL volumes of 2% APDC/DETC (1% w/v of each; Merck:Analar) were added per sample to extract adsorbed metals from carbonate surfaces. The extracting solution was buffered with NaOH (Analar) to a pH of five for effective chelation, and saturated with calcium (1 gram/L of $CaCl_2$) to prevent skeleton dissolution. Following extraction of adsorbed metals, and drying the skeletons at 110°C for 24 hours, skeleton dry weights were obtained to obtain a basis for measurement.

Samples were allowed to stand for twenty minutes at 20°C, then the extracts were poured through the perforated vial caps into beakers. Complete transfers were ensured using 25 mL follow-up rinses of Milli-Q water. Samples were acidified with one mL of HCl (12M Analar) before reducing volumes to 20 mL on a hotplate. 40 mL aliquots of $HNO_3:H_2O_2$ (1:1 mixture, Analar) were added to decompose residual organics, and the solutions were again reduced to <10 mL. Volumes were made up to 10 mL with 0.012M HCl for analysis.

Heavy metal concentrations were obtained by AAS, as described above.

Analysis of sediment. The duplicate samples collected from each site were mixed, and wet-sieved through polyethylene mesh with artificial seawater to divide the fine (<63 µm) and coarse fractions (>63 µm) for separate analyses as recommended by Förstner and Salomons (1980). Both sediment fractions were oven dried for six days at 55°C, and ground to a fine powder in a ceramic zirconium ring-mill prior to sequential extraction of heavy metals.

Exchangeable heavy metals were extracted following the procedure of Gillman and Sumpter (1986). About two grams of each sample were accurately weighed in 100mL beakers, 10 mL aliquots of $BaCl_2:NH_4Cl$ (0.1M of each component) were added, and the samples shaken for one hour on a rotary shaker. The samples were filtered through 0.45 µm cellulose acetate filters, and the sediments and filters returned to the beaker. Filtrates were boiled to near dryness, and made up to 10 mL with Milli-Q water.

Carbonate-bound heavy metals were extracted using the procedure of Tessier *et al.* (1979). Ten mL of sodium acetate trihydrate/acetic acid (1M each) were added to the sediments and filters, shaken for one hour, filtered through the rinsed filters, and the sediments and filters returned to their beakers. Five mL of nitric acid were added to the filtrates, which were boiled to near dryness and made up to 10 mL with Milli-Q water.

The procedure of Holmgren (1967), which is designed to mobilise metals bound by amorphous oxides, was used as the next extract. It should be noted that sulphides and labile metals bound by organics may also be included, if present. Ten mL of 30 g/L sodium dithionite and 90 g/L citric acid were added to the sediments and filters, then shaken for 13 hours prior to filtration. Filters were discarded at this point, and sediments were returned to their beakers. Ten mL of HNO_3:H_2O_2 (1:1 mixture) were added to the filtrates, which were boiled to near dryness, and made up to 10 mL with Milli-Q water.

The final extract represents heavy metals in residual phases, which may include organics resistant to earlier treatment, as well as more crystalline sulphides and oxides. Ten mL aliquots of aquaregia were added to the sediment samples, which were allowed to stand for one hour before boiling for 15 minutes. Cooled solutions were filtered, the filtrates boiled to near dryness, then made up to 10 mL with Milli-Q water.

Samples were analysed in duplicate by AAS as outlined above.

Statistical analysis. Two sample t-tests assuming unequal variance ($\alpha = 0.05$) were used to show differences in heavy metal concentrations between the different phases of sequential extraction. The five sites other than Mandorah Jetty were selected for comparison to avoid bias induced by the Zn outlier, because the harbour precincts represent estuarine conditions, rather than the jetty which represents a potential point source for pollution. When samples were below detection, 0 was substituted to obtain sample means and variances for comparative purposes. Two sample t-tests were firstly used to measure differences between the fine and coarse sediment fractions, and if significant differences were evident only the fine fractions were compared.

Interspecific and intersite differences in coral tissue and in coral skeleton were indicated using two sample t-tests.

RESULTS

The mineralogical composition of marine and estuarine sediment collected in the vicinity of Darwin Harbour is indicated in Table 1. Mineral phases listed in the coarse fraction which potentially can bind heavy metals are bioclastic carbonate, mica, fine sandstone fragments, and laterite pisoliths (iron and aluminium oxides). The role of these phases as heavy metal binding sites is indicated by the sequential extraction data, which shows metal concentrations obtained from various sediment fractions. Metal concentrations will be influenced both by the ability of particular phases to bind certain metals, as well as the concentration of those phases in the sediment.

The sequential extraction data is presented in Table 2. Within the exchangeable phases Pb, Cu, Ni and Cd appear to concentrate in the fine fraction, although this observation is qualitative because metal concentrations in the coarse fraction were consistently below detection limits, and therefore a t-test could not realistically be applied. However, significant differences between the fine and coarse fractions were measured for Cr and Zn in the aquaregia extract ($p = 0.004$ and 0.01 respectively), and in the sodium

Table 1. Description of the type and size fraction (% dry-weight) of collected sediment.

LOCATION	GRAINSIZE E (m)	WEIGHT (%)	SEDIMENT DESCRIPTION
Mandorah Jetty (Estuary sediment)	> 63 < 63	100 0	Tan, poorly sorted shelly sand (bivalve fragments, rounded quartz, laterite pisoliths)
Weed Reef (Estuary sediment)	> 63 < 63	100 0	Yellow, well sorted coarse micaceous sand (quartz, mica, minor shell fragments)
East Point (Estuary sediment)	> 63 < 63	96 4	Light tan, poorly sorted shelly sand (fragments of bivalves, echinoderms, and fine yellow sandstone)
Ludmilla Creek (Marine sediment)	> 63 < 63	95 5	Light tan, poorly sorted shelly sand (bivalve and coral fragments. Very minor laterite pisoliths)
North Shell Island (Marine sediment)	> 63 < 63	94 6	Light tan, very poorly sorted shelly sand (bivalve and echinoderm fragments. Very minor laterite pisoliths)
Old Man Rock (Marine sediment)	> 63 < 63	84 16	Light tan, poorly sorted shelly sand (bivalve fragments. Very minor laterite pisoliths)

Table 2. Heavy metals (ppm dry-weight) in sediment as the following reactive phases: a) exchangeable, b) carbonate, c) sodium dithionite/citric acid extractable, and d) residual phases.

		Exchangeable	Carbonate	Subtotal	Dithionite / citric acid extract	Resistant phases	Total
Cadmium (ppm)	Mandorah Jetty (sand)	0.1	0.1	**0.2**	0.3	0.4	**0.9**
	Weed Reef (sand)	nd	0.3	**0.3**	0.1	0.7	**1.1**
	East Point (sand)	nd	0.3	**0.3**	0.1	0.6	**1.0**
	East Point (fine)	0.6	0.4	**1.0**	0.2	0.2	**1.4**
	Ludmilla Creek (sand)	nd	0.3	**0.3**	0.3	1.0	**1.6**
	Ludmilla Creek (fine)	1.1	0.2	**1.3**	0.2	0.1	**1.6**
	North Shell Island (sand)	0.1	0.3	**0.4**	0.1	0.5	**1.0**
	North Shell Island (fine)	0.5	nd	**0.5**	0.1	0.2	**0.8**
	Old Man Rock (sand)	nd	0.3	**0.3**	nd	0.5	**0.8**
	Old Man Rock (fine)	0.4	0.2	**0.6**	0.1	0.2	**0.9**
Lead (ppm)	Mandorah Jetty (sand)	0.5	3.6	**4.1**	0.6	16.6	**21.3**
	Weed Reef (sand)	nd	5.1	**5.1**	1.2	5.5	**11.8**
	East Point (sand)	nd	6.2	**6.2**	nd	9.2	**15.4**
	East Point (fine)	0.3	4.2	**4.5**	nd	4.5	**9.0**
	Ludmilla Creek (sand)	nd	3.3	**3.3**	1.8	7.3	**12.4**
	Ludmilla Creek (fine)	1.3	2.7	**4.0**	2.8	6.0	**12.8**
	North Shell Island (sand)	0.5	2.7	**3.2**	1.4	8.7	**13.3**
	North Shell Island (fine)	0.8	1.3	**2.1**	1.9	9.5	**13.5**
	Old Man Rock (sand)	0.2	7.0	**7.2**	nd	5.7	**12.9**
	Old Man Rock (fine)	0.5	6.6	**7.1**	1.2	5.1	**13.4**
Copper (ppm)	Mandorah Jetty (sand)	nd	0.6	**0.6**	0.4	6.1	**7.1**
	Weed Reef (sand)	nd	0.4	**0.4**	nd	0.5	**0.9**
	East Point (sand)	nd	0.9	**0.9**	nd	1.9	**2.8**
	East Point (fine)	0.1	0.3	**0.4**	0.1	3.2	**3.7**
	Ludmilla Creek (sand)	nd	0.5	**0.5**	0.3	1.9	**2.7**
	Ludmilla Creek (fine)	0.3	0.4	**0.7**	0.3	1.4	**2.4**
	North Shell Island (sand)	nd	0.5	**0.5**	0.1	1.2	**1.8**
	North Shell Island (fine)	0.1	0.1	**0.2**	nd	2.9	**3.1**
	Old Man Rock (sand)	nd	0.3	**0.3**	nd	1.0	**1.3**
	Old Man Rock (fine)	0.1	0.3	**0.4**	nd	2.8	**3.2**

nd=not detected

Table 2 (cont.). Heavy metals (ppm dry-weight) in sediment as the following reactive phases: a) exchangeable, b) carbonate, c) sodium dithionite/citric acid extractable, and d) residual phases.

		Exchangeable	Carbonate	Subtotal	Dithionite / citric acid extract	Resistant phases	Total
Zinc (ppm)	Mandorah Jetty (sand)	0.1	37.9	**38.0**	34.9	56.0	**128.9**
	Weed Reef (sand)	nd	1.0	**1.0**	0.4	2.4	**3.8**
	East Point (sand)	nd	0.7	**0.7**	0.5	3.7	**4.9**
	East Point (fine)	0.4	1.3	**1.7**	2.8	9.2	**13.7**
	Ludmilla Creek (sand)	0.3	1.4	**1.7**	0.3	3.9	**5.9**
	Ludmilla Creek (fine)	0.2	0.5	**0.7**	3.3	6.6	**10.6**
	North Shell Island (sand)	0.2	0.4	**0.6**	0.4	4.3	**5.3**
	North Shell Island (fine)	1.0	0.7	**1.7**	2.2	11.5	**15.4**
	Old Man Rock (sand)	nd	nd	**nd**	0.1	3.9	**4.0**
	Old Man Rock (fine)	0.5	nd	**0.5**	0.8	9.0	**10.3**
Nickel (ppm)	Mandorah Jetty (sand)	0.8	2.4	**3.2**	1.3	3.1	**7.6**
	Weed Reef (sand)	0.1	2.5	**2.6**	0.5	5.1	**8.2**
	East Point (sand)	nd	2.6	**2.6**	0.2	4.7	**7.5**
	East Point (fine)	0.9	1.8	**2.7**	1.3	6.0	**10.0**
	Ludmilla Creek (sand)	nd	1.3	**1.3**	0.2	6.0	**7.5**
	Ludmilla Creek (fine)	1.4	1.1	**2.5**	0.4	4.8	**7.7**
	North Shell Island (sand)	1.0	2.3	**3.3**	0.4	2.6	**6.3**
	North Shell Island (fine)	0.9	2.5	**3.4**	1.2	6.0	**10.6**
	Old Man Rock (sand)	0.1	0.8	**0.9**	0.7	2.5	**4.1**
	Old Man Rock (fine)	1.0	1.1	**2.1**	0.8	8.1	**11.0**
Chromium (ppm)	Mandorah Jetty (sand)	0.1	1.8	**1.9**	2.4	15.0	**19.3**
	Weed Reef (sand)	nd	1.9	**1.9**	0.3	2.6	**4.8**
	East Point (sand)	nd	2.0	**2.0**	0.8	4.8	**7.6**
	East Point (fine)	nd	2.0	**2.0**	1.8	16.7	**20.5**
	Ludmilla Creek (sand)	nd	2.2	**2.2**	1.0	9.8	**13.0**
	Ludmilla Creek (fine)	0.3	1.8	**2.1**	1.7	13.5	**17.3**
	North Shell Island (sand)	nd	2.1	**2.1**	0.7	4.3	**7.1**
	North Shell Island (fine)	0.3	2.2	**2.5**	1.5	19.6	**23.6**
	Old Man Rock (sand)	nd	1.6	**1.6**	0.7	4.3	**6.6**
	Old Man Rock (fine)	nd	1.8	**1.8**	1.9	23.4	**27.1**

nd=not detected

Table 3. Heavy metal levels (ppm dry-weight) measured in *Montastrea annuligera* and *Goniastrea aspera* collected at the Weed Reef, East Point, and North Shell Island localities. P values for intersite and interspecific comparisons are listed in the bottom table.

Location	Species	Matrix	n	Cd			Pb			Cu		
				mean	S.E.	(Max.-Min.)	mean	S.E.	(Max.-Min.)	mean	S.E.	(Max.-Min.)
North Shell Island	*G. aspera*	Skeleton (ads)	3	0.33	0.26	(1.10 - nd)	0.37	0.09	(0.58 - 0.13)	0.04	0.03	(0.11 - nd)
		Tissue	6	1.41	0.38	(2.74 - 0.25)	80	24.7	(202 - 41.1)	11.4	5.5	(38.7 - 2.52)
East Point	*M. annuligera*	Skeleton (ads)	8	0.08	0.01	(0.13 - 0.03)	0.39	0.07	(0.68 - 0.13)	0.06	0.01	(0.10 - 0.02)
		Tissue	13	1.54	0.42	(4.65 - nd)	46.9	3.59	(73.9 - 26.1)	9.75	0.83	(16.1 - 5.43)
Weed Reef	*G. aspera*	Skeleton (ads)	3	0.07	0.05	(0.17 - nd)	0.34	0.06	(0.50 - 0.22)	0.07	0.04	(0.14 - nd)
		Tissue	5	1.67	0.65	(3.64 - 0.32)	62.3	10.3	(82.8 - 23.2)	14.7	7.3	(43.8 - 4.67)
	M. annuligera	Skeleton (ads)	6	0.1	0.03	(0.21 - nd)	0.44	0.09	(0.75 - 0.11)	0.08	0.02	(0.14 - nd)
		Tissue	8	1.88	0.45	(3.83 - nd)	39.3	4.69	(55.0 - 18.9)	10.6	0.87	(14.3 - 7.68)
Darwin (Total)	*G. aspera*	Skeleton (ads)	8	0.2	0.13	(1.10 - nd)	0.36	0.05	(0.58 - 0.13)	0.06	0.02	(0.14 - nd)
		Tissue	11	1.52	0.34	(3.64 - 0.25)	71.9	13.9	(202.2 - 23.2)	13	4.32	(44.2 - 2.54)
	M. annuligera	Skeleton (ads)	14	0.09	0.01	(0.21 - nd)	0.41	0.05	(0.75 - 0.13)	0.06	0.01	(0.14 - nd)
		Tissue	21	1.67	0.31	(4.66 - nd)	44	2.8	(73.9 - 18.9)	10.2	0.61	(16.3 - 5.48)

Location	Species	Matrix	n	Zn			Ni			Cr		
				mean	S.E.	(Max.-Min.)	mean	S.E.	(Max.-Min.)	mean	S.E.	(Max.-Min.)
North Shell Island	*G. aspera*	Skeleton (ads)	3	0.05	0.03	(0.12 - nd)	0.46	0.11	(0.73 - 0.17)	0.17	0.07	(0.35 - nd)
		Tissue	6	19.3	7.8	(48.9 - 3.63)	19.1	4.02	(28.4 - 0.87)	5.9	1.7	(12.8 - nd)
East Point	*M. annuligera*	Skeleton (ads)	8	0.07	0.03	(0.22 - nd)	0.5	0.1	(1.03 - 0.19)	0.18	0.11	(0.95 - nd)
		Tissue	13	5.46	1	(10.8 - 1.19)	22.3	3.66	(44.6 - nd)	3.54	1.31	(12.4 - nd)
Weed Reef	*G. aspera*	Skeleton (ads)	3	0.16	0.09	(0.35 - nd)	0.32	0.04	(1.29 - 0.42)	0.08	0.02	(0.13 - 0.03)
		Tissue	5	4.87	2.01	(12.0 - nd)	26.6	9.4	(59.0 - nd)	8	3.5	(19.6 - nd)
	M. annuligera	Skeleton (ads)	6	0.05	0.01	(0.10 - nd)	0.47	0.16	(1.10 - 0.07)	0.24	0.09	(0.53 - nd)
		Tissue	8	10.6	5.23	(46.6 - 1.75)	17.8	4.91	(43.7 - nd)	1.61	1.61	(12.9 - nd)
Darwin (Total)	*G. aspera*	Skeleton (ads)	6	0.1	0.05	(0.34 - nd)	0.39	0.06	(0.73 - 0.17)	0.13	0.04	(0.35 - nd)
		Tissue	11	12.7	4.77	(48.9 - nd)	22.5	4.68	(59.0 - nd)	6.85	1.78	(19.6 - nd)
	M. annuligera	Skeleton (ads)	14	0.06	0.02	(0.20 - nd)	0.48	0.09	(1.10 - nd)	0.2	0.07	(0.95 - nd)
		Tissue	21	7.48	2.08	(46.6 - 1.19)	20.6	2.91	(44.6 - nd)	2.81	1.01	(12.9 - nd)

Table 3 continued. P values for intersite and interspecific comparisons.

P values	Cd	Pb	Cu	Zn	Ni	Cr
Weed Reef: *G. aspera* vs. *M. annuligera*.	0.79	0.09	0.60	0.33	0.38	0.15
G. aspera: Weed Reef vs. North Shell.	0.74	0.52	0.72	0.12	0.33	0.62
M. annuligera: Weed Reef vs. East Point.	0.59	0.22	0.46	0.37	0.90	0.36

dithionite/citric acid extract ($p = 0.0002$ and 0.04 respectively). Differences for Cu in the aquaregia extract, and for Ni in the sodium dithionite/citric acid extract were not significant ($p = 0.07$ for both). Residual phases bind Cu, Zn, Ni and Cr relative to phases extracted by sodium dithionite/citric acid ($p = 0.0004$, 0.001, <0.000 and 0.004 respectively), carbonate phases ($p = 0.001$, 0.004, <0.000 and 0.004 respectively), and exchangeable phases ($p = 0.009$, 0.003, <0.000 and 0.003). The carbonate phases bind significantly more Pb, Cu and Ni than do sodium dithionite/citric acid extractable phases ($p = 0.002$, 0.002 and 0.001 respectively), and more Cr than do exchangeable phases ($p < 0.000$).

Table 3 is a summary of heavy metal concentrations measured in coral tissue and adsorbed onto coral skeleton, from three localities in the vicinity of Darwin Harbour. No interspecific variation is evident between *Montastrea annuligera* and *Goniastrea aspera*, and there is no evidence for variation between the three sites.

DISCUSSION

Heavy metal concentrations in harbour sediment. Less than two ppm of reactive heavy metals were represented by exchangeable phases, of which the fine fraction appears more effective than the coarse fraction at accumulating Pb, Cu, Ni and Cd. This agrees with findings of other authors who observe the capacity of fine sediment fractions to accumulate heavy metals relative to coarser fractions (Förstner 1989; Salomons and Förstner 1984; Harbison 1986). Reasons for this include a) the increased surface area to volume ratio in fine sediment, and b) the high cation exchange capacity of clay minerals which commonly occur in the fine fraction (Förstner and Salomons 1980).

With the exception of Zn at Mandorah Jetty, heavy metals extracted from carbonate-bound phases measured less than seven ppm. Carbonate phases play a significant role in binding Pb, Cu and Ni compared with sodium dithionite/citric acid extractable phases, and also binds significantly more Cr than do exchangeable phases. This probably reflects the relative abundance of carbonates relative to other mineral phases in the sediment, and consequently the importance of carbonates in the capacity of Darwin Harbour sediment to accumulate heavy metals. These results support observations by Kitano *et al.* (1976), who show that carbonate surfaces effectively adsorb Pb and Cu at low concentrations.

Heavy metals extracted by sodium dithionite/citric acid were less than four ppm, again with the exception of Zn at Mandorah Jetty. Cu, Ni, and Pb concentrations in this extract were similar to those measured in the exchangeable phases, with Cr and Zn being significantly higher in the fine fraction relative to the coarse fraction. Two possible reasons for elevated Cr and Zn extractable by sodium dithionite/citric acid in the fines include: 1) enhancement of the exchange capacity of the fine fraction by precipitation of iron oxides onto clay minerals (Jenne 1977), and 2) the presence of organic materials (Piccolo and Mbagwu 1989) which improves the binding capacity of the fines. If iron and aluminium oxides are present, they are capable of cation exchange with heavy metals (Kinniburgh *et al.* 1976; Alloway 1990), particularly since seawater pH exceeds the isoelectric point for most iron oxides and hydroxides (McConchie 1987). If organic phases are present, they also have metal binding potential (Raspor 1989). The ability of organic matter to bind Zn and Cu is discussed by a number of authors (Cooper and Harris 1974; Mackey and O'Sullivan 1990; Saenger *et al.* 1991).

Aquaregia extractable residual phases concentrate Cu, Zn, Ni and Cr in the fine fraction, and therefore provide significant heavy metal binding sites in Darwin Harbour sediment.

The Mandorah Jetty site has elevated Zn relative to other locations. There was a noticeably higher laterite component in the coarse fraction of this sediment compared with other locations, and one possible explanation for the elevated Zn is increased availability of iron-oxide binding sites. However because Zn is elevated in carbonate phases, as well as residual oxide and organic bound phases, the influence of another factor is probable. Since the samples were col-

Table 4. Heavy metal concentrations (ppm) from other studies. Note that metals are generally extracted by acid digestion, rather than by desorption as in this paper. Note also that Red Sea tissue concentrations are in dry-weight, while the Heron Island concentrations are in wet-weight. Values from the Red Sea represent (1) an unpolluted site, and (2) a polluted site. Values from Heron Island represent (1) Wistari Reef, and (2) Heron Island marina.

	Location	Genus	Cd	Pb	Cu	Zn	Ni	Cr	Reference
SKELETON	Darwin Harbour	*Montastrea*	0.09	0.41	0.06	0.06	0.48	0.2	this study
	Darwin Harbour	*Goniastrea*	0.2	0.36	0.06	0.1	0.39	0.13	this study
	Caribbean	*Siderastrea*	7.5-7.6	31.0-32.3	2.0-3.8	8.9-10.2	91.6-93.7	7.3-9.9	Guzman *et al.*(1992)
	Florida Keys	*Siderastrea*	<0.3	<1.0-11.0	4.0-10.0	-	-	-	Glynn *et al.*(1989)
	Florida Keys	*Porites*	<0.3	<1.0-11.5	6.0-90.0	-	-	-	Glynn *et al.*(1989)
	Virgin Islands	*Montastrea*	-	0.09 - 0.39	-	-	-	-	Dodge and Gilbert (1984)
	Hong Kong	*Platygyra*	0.055-2.62	0.206-0.793	7.87-8.57	-	-	-	Scott (1990)
	Red Sea (1)	*Goniastrea*	0.035	36	0.817	1	0.05	-	Hanna *et al.* (1990)
	Red Sea (2)	*Goniastrea*	0.045	47	0.92	2.85	0.21	-	Hanna *et al.* (1990)
	Red Sea (1)	*Porites*	0.042	44	0.775	3.38	0.11	-	Hanna *et al.* (1990)
	Red Sea (2)	*Porites*	0.058	51	0.834	9.28	0.15	-	Hanna *et al.* (1990)
	Heron Island (1)	*Goniastrea*	0.06	0.05	0.07	1.5	-	-	McConchie *et al.*(1992)
	Heron Island (2)	*Goniastrea*	<0.05	0.1	0.12	2.7	-	-	McConchie *et al.*(1992)
	Heron Island (1)	*Porites*	0.14	0.18	0.09	1.4	-	-	McConchie *et al.*(1992)
	Heron Island (2)	*Porites*	0.06	0.58	0.12	4.7	-	-	McConchie *et al.*(1992)
TISSUE	Darwin Harbour	*Montastrea*	1.67	44	10.2	7.48	20.6	2.81	this study
	Darwin Harbour	*Goniastrea*	1.52	71.9	13	12.7	22.5	6.85	this study
	Red Sea (1)	*Goniastrea*	0.013	28	2.99	259	0.75	-	Hanna *et al.* (1990)
	Red Sea (2)	*Goniastrea*	0.01	29	4.54	1790	1.4	-	Hanna *et al.* (1990)
	Red Sea (1)	*Porites*	0.01	11	4.9	233	2.4	-	Hanna *et al.* (1990)
	Red Sea (2)	*Porites*	0.013	30	5.04	770	3.87	-	Hanna *et al.* (1990)
	Heron Island (1)	*Goniastrea*	3.27	1.17	3.26	12.6	-	-	McConchie *et al.*(1992)
	Heron Island (2)	*Goniastrea*	1.96	5.95	14.81	59.3	-	-	McConchie *et al.*(1992)
	Heron Island (1)	*Porites*	3.43	2.96	1.99	11.3	-	-	McConchie *et al.*(1992)
	Heron Island (2)	*Porites*	1.88	7.59	4.97	51.8	-	-	McConchie *et al.*(1992)

lected at the ferry terminal, the likely Zn source is sacrificial anodes which are commonly used in boats.

Heavy metal levels in scleractinian corals. Samples of *Goniastrea aspera* and *Montastrea annuligera* collected from North Shell Island, East Point and Weed Reef were analysed for heavy metal concentrations in coral tissues and adsorbed or included in coral skeletons. Heavy metal concentrations measured within coral tissues represent those biologically accumulated, and bound firmly enough to withstand exposure to EDTA. Heavy metals adsorbed onto coral surfaces or included in particulate matter contained within the coral skeleton are thought to indirectly represent the chemistry of the surrounding water mass (St John 1974; Goreau 1977). This study is designed to represent heavy metals contained in corals on the basis of these ideas.

Interspecific differences were not evident between *Goniastrea aspera* and *Montastrea aspera* at Weed Reef, either in coral tissue or adsorbed onto coral skeleton. Neither was there a significant difference in heavy metal levels measured between East Point and Weed Reef in *Montastrea annuligera*, or between North Shell Island and Weed Reef measured in *Goniastrea aspera*. On this basis, intersite variation is not evident between the three locations.

In studies by other workers (Table 4) conducted in the Red Sea, Hong Kong Harbour, and the Pacific Ocean, significant differences in heavy metal levels were measured in corals from polluted sites relative to control sites (Dodge and Gilbert 1984; Hanna and Muir 1990; Scott 1990). Hanna and Muir (1990) indicated this for three coral species in both coral tissue and skeleton, while Dodge and Gilbert (1984), and Scott (1990) showed this in coral skeleton alone. Both McConchie and Harriott (1992), and Hanna and Muir (1990) have shown significant intersite variations for Zn in coral tissue. However, the observations by McConchie and Harriott (1992) that Cd and Pb concentrate in coral tissue relative to skeleton differ from those of Hanna and Muir (1990), who observed higher values of these metals in coral skeleton. It seems therefore that results are being confounded, possibly by different sample treatments, or by biological factors such as different sites or bioregulation. Harland and Nganro (1990), and Harland *et al.* (1990) have shown the ability of coelenterates to bioregulate elevated heavy metal levels by mechanisms which include a) expulsion of zooxanthellae which can accumulate heavy metals, and b) secretion of mucus which might restrict metal uptake. Nevertheless, the response of coelenterates to long term exposure of sublethal heavy metal levels has still to be studied.

On the basis of available information, corals have potential as biological monitors of heavy metal concentrations in the vicinity of Darwin Harbour for the following reasons:

1) They are well represented in the harbour precincts relative to other suitable organisms. The two species indicated in this study are present at a number of sites, providing a species control and a basis for replication;

2) The sedentary nature of corals means that they represent the study area;

3) The long lived nature and large size of corals support their use in repeated measure studies, since portions of the same colony can be sampled over long time periods if a suitable colony is given conservation status. Dodge and Gilbert (1984) were able to measure temporal variation in Pb levels recorded in the skeleton of *Montastrea annularis*;

4) Corals can accumulate measurable levels of heavy metals in their skeleton as well as in their tissue. The capacity of coral tissue to absorb dissolved matter (Pilson 1974; Drew Ferrier 1991), and ingest particulate matter (Goreau 1977) indicate a range of mechanisms by which corals can take up heavy metals. At this stage, variation in heavy metal concentrations evident both in coral tissue and skeleton can be accounted for by suitable replication and data treatment. The right skews present in some of the tissue data (*e.g.* Pb in the tissue of *Goniastrea aspera*, and Zn in *Goniastrea aspera* and *Montastrea annuligera*) should be considered, and could be induced by biological factors such as the concentration of zooxanthellae in coral tissue. On this basis, further work needs to be conducted in order to indicate the degree of variation resulting purely from biological factors before the full potential of corals as biological monitors is realised.

The baseline results provided in this paper indicate pre impact concentrations of heavy metals in coral tissue and adsorbed onto coral skeleton, upon which future comparisons can be made.

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EPIBIOSIS AND THE SPATIAL DISTRIBUTION OF MOLLUSCS ON THE PYLONS OF MANDORAH JETTY, DARWIN HARBOUR.

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ABSTRACT

An assemblage is described in which oysters (*Saccostrea* sp.) provided microhabitat for several species of gastropod. Relatively little variation in vertical distribution or abundance of molluscs was found at either of the two scales studied. Species were randomly distributed with respect to aspect, with the exception of *Littoraria articulata*, which occurred in greater numbers on northern faces than on southern faces of some pylons. The potential contribution of the results to latitudinal comparisons is discussed. A study of the epibiotic relationship between limpets (*Patelloida mimula*) and oysters found that limpets were more abundant on dead oyster shells than on living oysters. Monitoring the movements of marked individuals revealed that limpets were more likely to disperse from live than from dead oysters over periods of up to a week.

KEYWORDS: artificial substratum, epibiosis, microhabitat, spatial autocorrelation, vertical distribution, limpet, littorinid, oyster.

INTRODUCTION

Attempts to make latitudinal comparisons of patterns of distribution of organisms living on marine hard substrata have been frustrated by a lack of data from tropical habitats (Lubchenco *et al.* 1984). These authors identified a need for quantitative descriptions of intertidal communities on tropical hard substrata and stressed the value of such data for workers with a range of research interests. Tropical shores do not, as was previously supposed (Moore 1972), have generally smaller tidal ranges than temperate shores (Longhurst and Pauly 1987). Despite this, research in the tropics has largely been concentrated on shores where the tidal range is small (Brosnan 1992). There are, therefore, disproportionately few studies of tropical areas with large tidal ranges and this imbalance may confound interpretation of latitudinal trends. Darwin Harbour is a tropical embayment with a tidal range of up to 7.8 m (Saenger *et al.* 1977). As such, it offers an opportunity to study a tropical intertidal assemblage experiencing a large tidal range.

This study examined the intertidal molluscan epifauna of pylons supporting the Mandorah Jetty in Darwin Harbour. Assemblages of organisms living epifaunally on artificial structures such as jetties have been studied to investigate succession (Sutherland 1974), patch dynamics (Kay and Keough 1981), competition (Russ 1982), predation (Russ 1980) and the concept of community stability (Kay and Butler 1983). Before proposing and testing models invoking processes such as these, however, it is first necessary to describe quantitatively the patterns of distribution and abundance of the organisms present (Underwood 1991). An integral part of this process is to identify the scales at which patterns exist and the degree to which they are statistically significant (Andrew and Mapstone 1987). Without this information it is not possible to propose relevant explanatory models or to design experimental tests of them at spatial scales appropriate to the system (Legendre and Fortin 1989; Levin 1992).

Gradients of exposure along temperate coasts have consistently been characterised by differ-

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In: Hanley, J.R., Caswell, G., Megirian, D. and Larson, H.K. (eds). *Proceedings of the Sixth International Marine Biological Workshop. The marine flora and fauna of Darwin Harbour, Northern Territory, Australia.* Museums and Art Galleries of the Northern Territory and the Australian Marine Sciences Association: Darwin, Australia, 1997: 411–424.

ences in patterns of distribution of intertidal organisms (e.g. Menge 1976; Underwood 1981; Underwood and Jernakoff 1984; McQuaid and Branch 1984). The pylons of Mandorah Jetty are circular in cross-section and thus assemblages of molluscs living on them experience a variety of physical conditions according to aspect: the seaward faces of the pylons are more exposed to waves than are the landward (or leeward) faces and different aspects of pylons also receive differing amounts of direct sunlight and shade. Although the works cited above described relatively large-scale patterns, it was hypothesised that processes giving rise to them could also act at the smaller scales examined in the present study, particularly if the causal processes involve the behaviour of molluscs (e.g. Menge 1978; Underwood and Jernakoff 1984). It was predicted that there would be discernible patterns of distribution in relation to aspect and that those patterns would show some consistency from pylon to pylon.

Species living on intertidal substrata are often described as occurring in distinct vertical bands or 'zones' (Stephenson and Stephenson 1972). Menge and Lubchenco (1981) describe less distinct patterns of zonation in the Bay of Panama than those seen on many temperate coasts. Patterns of vertical distribution of molluscs, barnacles and algae on the pylons of Mandorah Jetty are described below.

Spatial autocorrelation is a procedure suitable for describing patterns. It was first proposed by the geographers Cliff and Ord (1973) and has gradually found its way into biology, receiving early notice by Jumars *et al.* (1977) and a comprehensive treatment by Sokal and Oden (1978a, b). It provides an index of correlation between sampling units of specified degrees of spatial separation. The significance of the index can be tested using randomization procedures, yielding an objective measure of the scales at which sampling units are dependent (i.e. at which spatial patterns are apparent).

The structure of the jetty made it a convenient environment in which to examine assemblages at several spatial scales. Each pylon was considered as a 'site' and, since the pylons are arranged from the shore out into the Harbour, it was possible to make a comparison between 'landward' and 'seaward' sites (Fig. 1). At smaller scales, 'within site' patterns of distribution along two axes, horizontal and vertical, were sampled.

Epibiosis of *Patelloida mimula.* At even smaller spatial scales, patterns of distribution of organisms may be explained by their association with features of microhabitat. When the microhabitat in question is biotic in origin, the association is termed 'epibiosis' (see review by Wahl 1989). Epibiotic associations are particularly common among species of limpets (Branch 1981), with documented examples even extending back to the Late Cretaceous period (Zinsmeister 1990). The acmaeid limpet, *Patelloida mimula*, is commonly found in both mangrove and sheltered rocky shore habitats in the Sydney region. Individuals in these temperate populations are found almost exclusively on the valves of the Sydney rock oyster, *Saccostrea cucullata* (Creese 1978; Ponder and Creese 1980; Crowe unpubl. data). The limpets were found in greater densities on dead oyster shells (referred to as 'dead oysters' hereafter) than on those still containing a living oyster ('live oysters') (Creese 1978; Crowe unpubl. data). The co-occurrence of oysters and *Patelloida mimula* in tropical Darwin Harbour provided an opportunity to assess the generality of these patterns.

Among species of epibiotic limpet, there is variation in the amount of time that individuals remain 'faithful' to individual host organisms. *Acmaea asmi* frequently moved from one host to another, with only 40% remaining on a host for more than an hour (Eikenberry and Wickizer 1964). Mapstone *et al.* (1984) marked individuals of *Patelloida mufria* and their trochid hosts and found that after four days all but about 20% of marked limpets had changed hosts. At the other extreme, Scheibling *et al.* (1990) used a correlation between sizes of *Patelloida nigrosulcata* and hosts (*Haliotis roei* or *Patella laticostata*) to infer lifelong associations between individuals. Preliminary measurements were made of the proportion of individuals of *P. mimula* remaining on specific host oysters on the Mandorah Jetty over periods of up to a week.

The observation that limpets are less common on live than on dead oysters (see above and Results) could be explained by three broad classes of model: differential settlement, differential mortality or behaviour (see Underwood 1979 and Underwood and Denley 1984). A behavioural model was proposed in which, although limpets spend time on both substrata as they gradually disperse over the 'landscape', they spend more time on dead than on live shells. If this model is correct, it can be predicted that, after a week, there would be a smaller proportion of marked individuals remaining on live hosts than dead shells. This hypothesis was tested by marking a number of individuals on live and dead shells and comparing rates of dispersal.

METHODS

Study site. The study was done on the concrete pylons supporting the Mandorah Jetty (Fig. 1). The jetty is orientated east-west and has 19 pairs of vertical pylons interspersed with four pairs of larger pylons that were inclined from the vertical (Fig. 1). The distance between pairs of pylons is 6.5 m. The pairs of pylons were numbered from the landward end of the jetty (omitting the first two pairs and the inclined pylons). Pairs 1-6 were grouped as the 'landward' pylons and pairs 9-14 represent the 'seaward' pylons. The northern pylon in each pair was denoted 'b' and the southern 'a', so that each pylon had an individual number/letter code. Data were collected in the dry season, when the prevailing winds are trade winds from the southeast (J. R. Hanley, pers. comm.).

On one pylon from each pair a datum mark was established using the following method. At the time given in tide tables, the morning low tide was assumed to be at the height predicted. A mark was made at that level and also at the predicted height of that afternoon's high tide (using the low tide mark as a reference point). At the time given for high tide, the height of the tide relative to the mark was observed using binoculars. If the water level coincided with the mark, both marks were taken to be accurate for that pylon. If the water level and mark did not coincide, the discrepancy was noted and an adjustment made to the marks. This method is based on the assumption that the tide table for Darwin Harbour supplied by the Darwin Port Authority provided accurate predictions of time and heights of tide for the jetty during the study. Since tides are known to vary according to local conditions such as wind speed and direction, there is some inaccuracy inherent in the above method.

Distribution of molluscs. Two pylons were randomly selected in each of the landward and seaward zones. Two replicate belt transects encircling each pylon ('circular transects') were sampled; a belt transect was 17 contiguous quadrats (0.09 x 0.09 m) around the pylon.

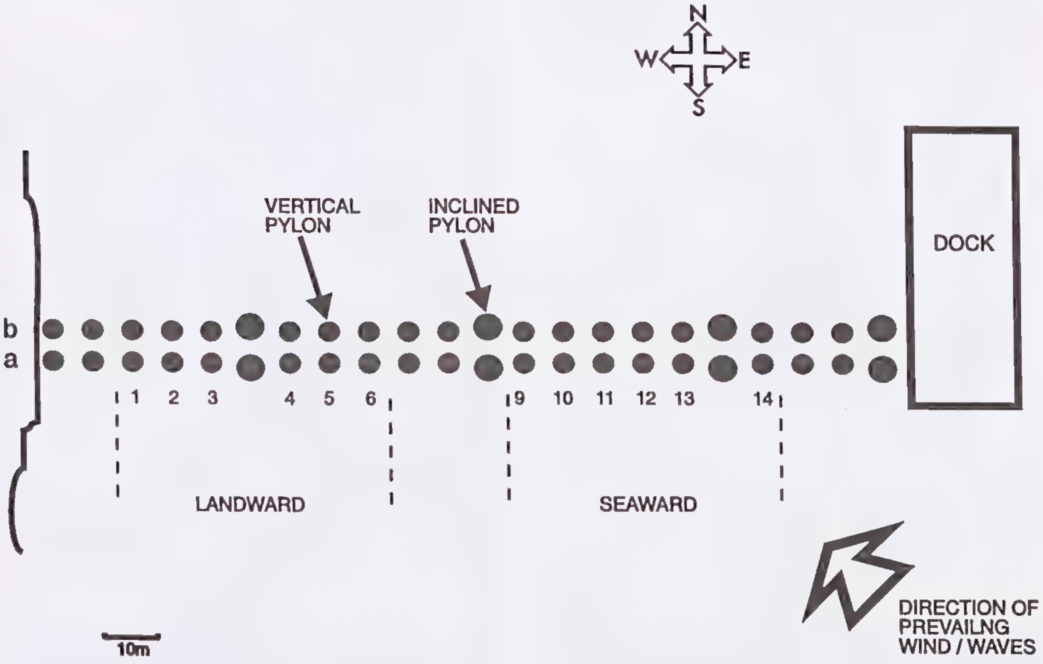

Fig. 1. Schematic diagram of pylons supporting the jetty at Mandorah (overhead view with walkway omitted). Number and letter codes for pylons as well as landward and seaward groupings are shown (see text for details).

Quadrat 1 was orientated due north in each case. The replicate transects were adjacent to one another above and below a line 5 m (approx.) above Chart Datum (C. D.).

For each quadrat, the following were recorded: percentage cover of oyster shells, the percentage of the oysters present that were dead, percentage cover of algae, abundance of *Patelloida mimula*, abundance of *Bembicium auratum*, abundance of *Littoraria articulata*. In this preliminary study, percentage cover was estimated visually and the data therefore provide only broad estimates. The technique does not allow the resolution of small differences in percentage cover, especially for coverage in the range of 30 to 70%.

Data for each species were analysed for spatial autocorrelation to test the null hypothesis that individuals were randomly distributed with respect to orientation. Details of the calculation of indices of spatial autocorrelation are presented in Cliff and Ord (1973) and Sokal and Oden (1978a). These formulae were adapted for the analysis of transects of contiguous quadrats. A programme was written in BASIC 6 to calculate autocorrelation coefficients (Moran's I) for all possible distances between quadrats ('step values' from 1 to 16) and to compare them to test distributions generated by randomization of the data (2000 permutations). The degree of autocorrelation plotted against the spatial separation of sampling units is known as a 'correlogram' (e.g. Fig. 3). At the largest step values, results are unreliable because only a few samples are compared, so these points are not always plotted on correlograms. Notes on the interpretation of correlograms are provided by Sokal (1979) and Legendre and Fortin (1989).

Patterns of vertical distribution of molluscs were examined on two randomly-selected pylons in each of the landward and seaward zones. Two replicate transects of 17 contiguous 0.09 x 0.09 m quadrats were sampled on each pylon. The upper edge of quadrat I was placed at 5.5 m above C.D. in each case. This height corresponded to the upper limit of distribution of oysters. Above that height, only barnacles were present. Since some significant orientation of one species was found in the circular transects (see Results), this was taken into account when placing vertical transects: all vertical transects were placed on the north faces of pylons. The same variables were recorded in the vertical transects as described for the circular transects.

To provide an approximate comparison of patterns of abundance between the landward and seaward areas, the quadrats in each transect were pooled to give a single sample of abundance or percentage cover as appropriate. Mean abundances or percentage covers of each species were plotted using the four transects sampled in each of the landward and seaward areas (Fig. 6). Due to limitations in the accuracy of measurement of percentage cover (discussed above), apparent differences were not analysed statistically.

Epibiosis of *Patelloida mimula*. *(a) Patterns of distribution*. The distribution of *Patelloida mimula* with respect to microhabitat was assessed in two ways: (a) the correlation of numbers of limpets with percentage cover of oyster shells was calculated for the combined quadrats of all the circular transects. (b) In order to test the hypothesis that *P. mimula* is found in greater densities on the shells of dead oysters (usually only the lower valve was present) than on live oysters, the following sampling was done: on each of four haphazardly-selected pylons in the landward zone, two 0.09 x 0.09 m quadrats were haphazardly placed at mid-tidal level. In each quadrat, the limpets occupying the shells of live or dead oysters were counted and the surface areas (A) of live and dead oyster shell present were estimated by measuring the maximal length (L) and breadth (B) of each oyster shell and then using the formula for the area of an ellipse: $\text{Area} = \pi/4(L+B)$. The overall proportions of limpets occurring on the two types of shell were compared to the proportions expected by chance given their relative availability (total area of each type) by χ^2 analysis.

(b) Preliminary study of rates of dispersal from host oysters. Four pylons at the landward end of the jetty were randomly selected. Since the seaward faces of pylons are exposed to more wave-action than their landward faces, it was hypothesised that limpets living on seaward faces may be less likely to disperse from home-scars than those living on landward faces. Samples of oysters and associated limpets were therefore stratified according to aspect; two pylons were sampled on their 'landward' faces and two on the 'seaward' aspect. Twenty oysters, each with one or more limpets living on their shells, were selected on the appropriate face of each pylon. It was noted whether the oysters were alive or dead (i.e. an empty lower valve). The limpets were marked with an individually

coded pair of dots of coloured enamel paint. A corresponding mark was made on the host oyster. The limpets were checked after two days, three days and seven days for departures from 'home' oysters. The start of the experiment was staggered over two days (8 July and 10 July) with one landward face and one seaward face being set up on each day.

(c) Movements with respect to live and dead oysters. The same data-set was used to examine the movements of limpets relative to live and dead oysters. Very few marked limpets moved, so results are presented in terms of the net changes in the total populations of limpets inhabiting the surfaces of marked oysters of the two types (including marked limpets and unmarked limpets that moved onto marked oysters during the study). Interpretation was, however, hampered by the fact that considerably fewer live than dead oysters had been marked (15 live vs 65 dead).

In order to correct that imbalance, a further trial was done in which 25 limpets on live oysters and 25 limpets on dead oysters were marked (as described above) on each of two pylons. The limpets were checked 1 day (17 July) and 7 days (23 July) later and their positions relative to 'home' oysters were noted.

RESULTS

Distribution of molluscs. *(a) Patterns of circular distribution.* The seaward pylons sampled were 11a and 12b and the landward pylons were 2b and 3a (see Fig. 1). No consistent patterns were detected for any species except *Littoraria articulata. Littoraria* were more abundant on the northern half of the pylons at the seaward site, with very few individuals occurring in quadrats 8, 9, 10 and 11 on the southern faces of any seaward transect (Fig. 2). This pattern was not seen on the landward pylons. Autocorrelation analysis revealed that the north - south pattern was significant in three of the four seaward transects (significant negative autocorrelation at step values of 8, 9, or 10 - Fig. 3 a, b and d). It was therefore decided to sample vertical transects on the northern faces of the pylons, where there were the greatest number of *Littoraria*.

(b) Patterns of vertical distribution. Patterns of vertical distribution showed relatively little variation among pylons and, in general, there were no large differences between landward pylons and seaward pylons (with one exception - see below). These generalities are exemplified by the data for oysters (Fig. 4). The patterns of distribution of the other species are illustrated with data from a single pylon (11a) (Fig. 5). The following description is based on all four of the pylons surveyed (2a and 3a (landward), 11a and 12a (seaward)).

Barnacles were only present higher than 4.96 m above C.D. There were no barnacles recorded in the transects on pylon 3a. In the area between 4.96 and 5.5 m, patches of barnacles were interspersed with patches of oysters. Below that, cover of oysters was generally 100% and oysters continued to form a dense cover at tidal heights lower than the area sampled. There was considerable variation in the proportion of dead oyster shells present. No consistent trends were apparent in the seaward pylons, where proportions of dead oysters ranged from 0 to 100% among quadrats. Landward pylons were covered by greater proportions of dead oyster shells than were seaward pylons. This was the only clear difference in 'abundance' between the two areas (Fig. 6). In the upper 0.5 m of transects on pylon 3a there were few oysters present and most were dead. A large proportion (50% on average) of oysters in both transects on pylon 2a were dead.

Of the grazers, *Littoraria* had the most restricted range; individuals were most abundant in the upper shore, from 4.69 to 5.5 m and only a few individuals were found in quadrats below

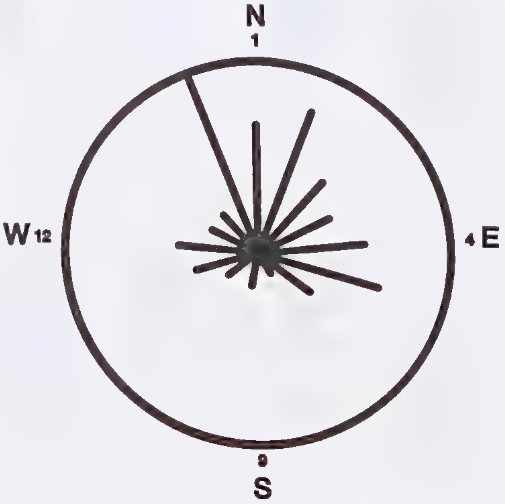

Fig. 2. Circular plot of abundance of *Littoraria* with respect to aspect. Data are the combined totals from each of quadrats 1 (North) to 17 on four circular transects: two on each of pylons 12a and 11b (from the seaward area of the jetty). **N** = north, **E** = east, **S** = south and **W** = west. The associated numbers refer to the corresponding quadrats in the transects.

that level. *Bembicium auratum* occurred in greatest abundance around 4.8 m (MHWN), where up to 10 animals per quadrat were found. Only one group of *Bembicium* was found above 5.14 m, but individuals were present in the lowest quadrats sampled (4.06 m). All individuals were less than 4 mm wide at their apertures. *Patelloida mimula* were distributed throughout the area where there was complete cover of oysters. The maximal recorded density was 10 per quadrat, but numbers were usually much smaller, the overall mean being 2.13 per quadrat (263.3 m^{-2}). Distribution was patchy but greater numbers were generally found between 4.33 and 5.23 m. None was found above 5.23 m.

Below MHWN (4.8 m), the oysters were partially covered in unidentified epiphytic algae. There was a trend for algae to be more abundant on landward than seaward pylons, but variation between pylons was relatively large.

Epibiosis of *Patelloida mimula.* *(a) Patterns of distribution.* The correlation between abundance of *P. mimula* and percentage cover of oysters in the circular transects was significant ($r = 0.44$, $P < 0.01$. Fig. 7), but oysters accounted for little (about 19%) of the variability in the abundance of limpets.

Significantly more *Patelloida mimula* were found on dead oyster shells than on live oyster shells than expected by chance given the availability of the two substrata ($\chi^2 = 44.21$, $P < 0.005$. Table 1).

(b) Preliminary study of rates of dispersal. After seven days, 84% (21 of 25 individuals) of the limpets marked on each of the landward faces of pylons were on their original hosts on each of the two pylons examined. On the seaward sides, 91.7% (22 of 24 individuals) and 95.8% (21 of 24) of limpets were found on their original host oysters on the two pylons (Fig. 8a). Although there were fewer departures from hosts on the seaward sides of pylons than from those on landward sides, the difference was only a matter of one or two limpets in each case and cannot be interpreted as strong evidence of different rates of dispersal from the oysters on the different faces of pylons.

(c) Movements with respect to live and dead oysters. After two days, the net changes in the populations of limpets inhabiting marked live oysters and marked dead oysters were small. After a week, however, there had been a small net increase of two limpets on dead oysters, making a total of 88 (a 2% increase), but a net

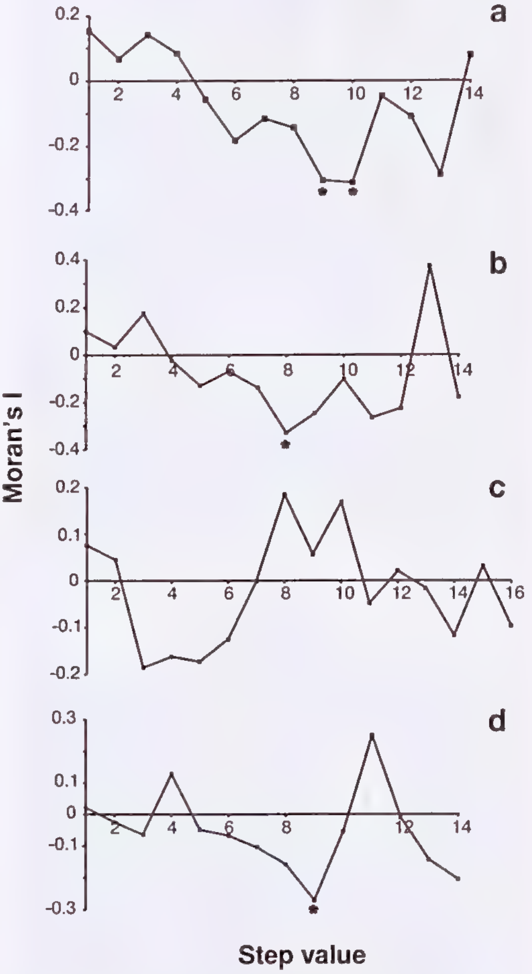

Fig. 3. Correlograms for patterns of circular distribution of *Littoraria* on the seaward pylons. (a) transect 1, pylon 11b, (b) transect 2, pylon 11b, (c) transect 1, pylon 12a, (d) transect 2, pylon, 12a. * denotes significant autocorrelation at that step value.

Table 1. χ^2 analysis to test the null hypothesis that limpets are found on live and dead oyster shells in proportion to their availability.

State of oyster	No. of *Patelloida* Observed	Area of shell available (cm^2)	No. of *Patelloida* Expected	Statistics
Live	6	225	25.75	$\chi^2 = 44.21$
Dead	32	107	12.25	$P < 0.001$

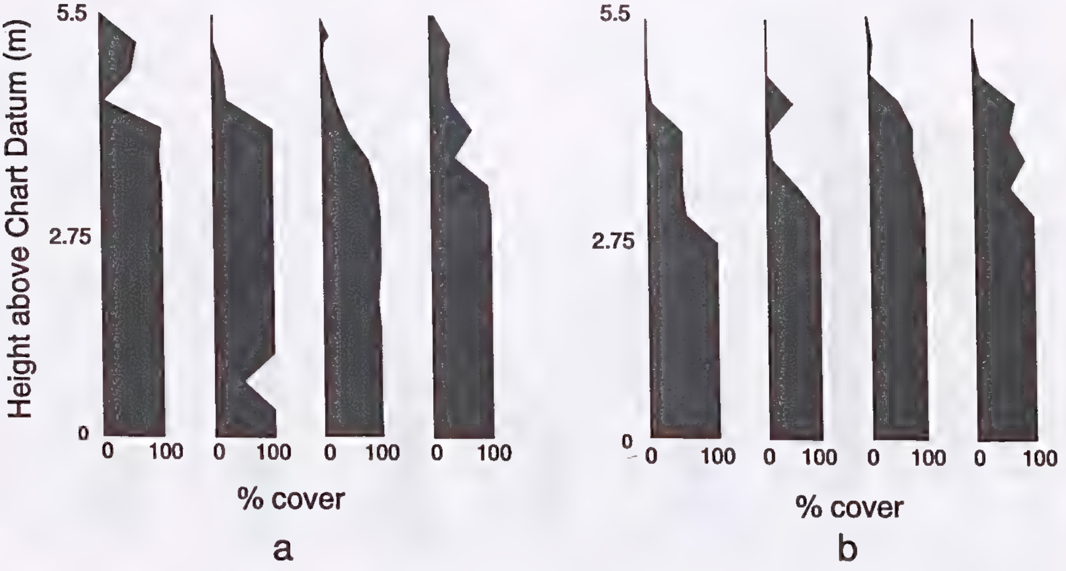

Fig. 4. Patterns of vertical distribution of the oyster, *Saccostrea*. **(a)** Seaward pylons (from left to right: transect 1, pylon 11a; transect 2, pylon 11a; transect 1, pylon 12a; transect 2, pylon 12a.) **(b)** landward pylons (from left to right: transect 1, pylon 2a; transect 2, pylon 2a; transect 1, pylon 3a; transect 2, pylon 3a.)

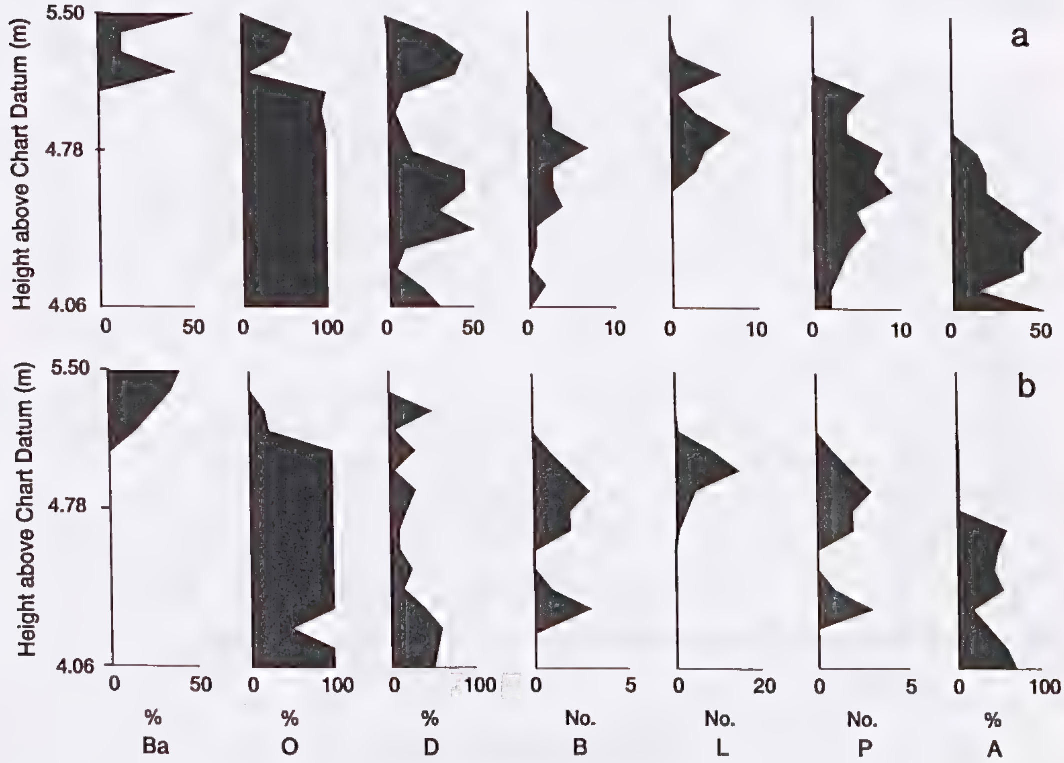

Fig 5. Patterns of vertical distribution of all species on pylon 11a. **(a)** Transect 1, **(b)** Transect 2. **Ba** = barnacles (percentage cover), **O** = oysters (percentage cover), **D** = percentage of oysters present that are dead, **B** = *Bembicium auratum* (abundance), **L** = *Littoraria* (abundance), **P** = *Patelloida mimula* (abundance), **A** = algae (percentage cover - secondary).

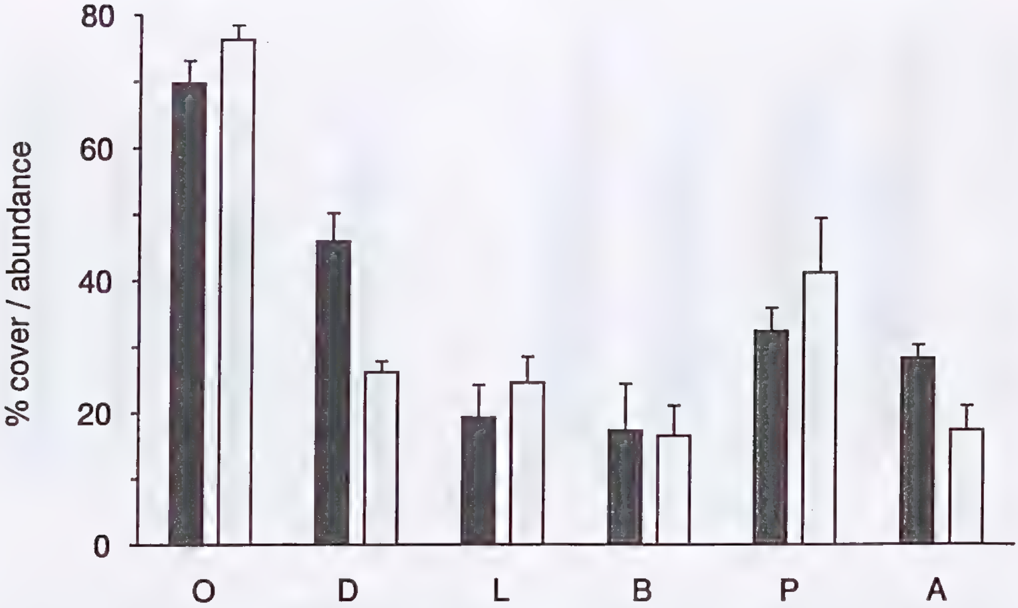

Fig. 6. Comparison of abundance / percentage cover (as appropriate) between landward and seaward pylons. For each species, mean abundance / percentage cover from four transects (2 on each of 2 pylons in each area) with S.E. is shown. **O** = oysters (percentage cover), **D** = percentage of oysters present that were dead (i.e. lower valve only), **L** = *Littoraria* (abundance), **B** = *Bembicium auratum* (abundance), **P** = *Patelloida mimula* (abundance), **A** = algae (percentage cover - secondary). ▆ = landward pylons, ☐ = seaward pylons.

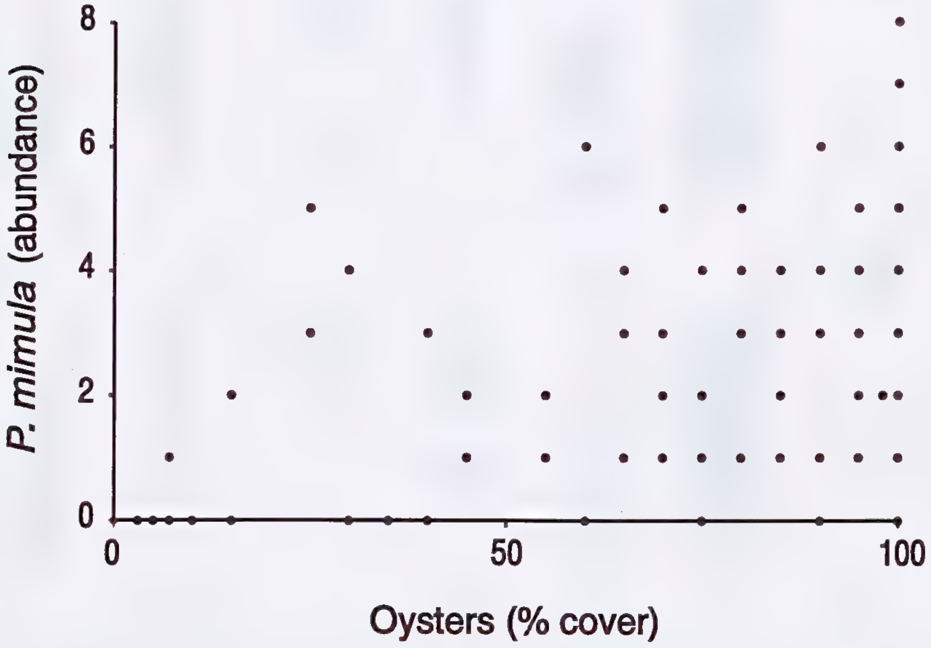

Fig. 7. Abundance of *Patelloida mimula* plotted against percentage cover of oysters. Combined data from all circular transects. $n = 134$, $r = 0.44$ ($P<0.01$). The arrangement of points shows some degree of regularity because percentage cover of oysters was estimated only to the nearest 5%.

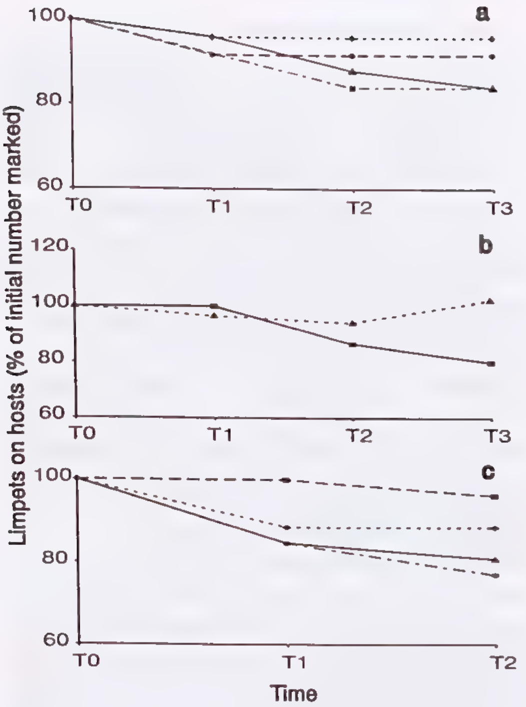

Fig. 8. Dispersal of marked *Patelloida mimula* from host oysters. (a) - -●- - = seaward face, pylon 3a; - - ♦ - - = seaward face, pylon 2b; – - ■ - – = landward face, pylon 2a, —▲— = landward face, pylon 3b. T0 = start of trial, T1 = 2 days later, T2, = 3 days later, T3 = 7 days later. (b) data from same trial as 'a' (above), but divided into populations of limpets on live oysters (—■—) and dead oysters (- - ▲ - -). All arrivals and departures of limpets (marked and unmarked) to and from the marked oysters are included. 100% limpets on live oysters = 15 individuals, 100% limpets on dead oysters = 86 individuals. (c) - - ♦ - - = limpets on dead oysters, pylon 3a (100% = 26 individuals), – —■— – = limpets on dead oysters, pylon 3b (100% = 25 individuals), – - ● - – = limpets on live oysters, pylon 3a (100% = 26 individuals), —▲— = limpets on live oysters, pylon 3b (100% = 25 individuals). T0 = start of trial, T1 = 1 day later, T2 = 1 week later.

loss of three limpets from the original population of 15 on live oysters (a 20% loss) (Fig. 8b).

In the second trial, in which equal numbers of limpets were marked on live and dead oysters, a similar result was found. After a week, 77% and 81% of the limpets marked on live oysters remained on their original hosts on the two replicate pylons. On the same pylons, 88% and 96% of the limpets that were marked on dead oysters remained (Fig. 8c). Thus there was a consistent trend for greater rates of dispersal from live than from dead oysters. Due to the small numbers of movements of marked limpets, no formal analyses were done.

It is also interesting to note that there were two instances in which limpets were absent from a host on one day (in one case approximately 30 cm away) and were then found to have returned to the original host at a later time.

DISCUSSION

Distribution of molluscs. No consistent patterns of distribution with respect to aspect were found for oysters, *Bembicium auratum* or *Patelloida mimula*. This result seems to falsify the model that the assemblage of molluscs is significantly altered by changes in the physical environment at that scale. Oysters are firmly attached to the substratum and lived in the entire range of physical conditions encountered at that level on the pylons. The gastropods, *Patelloida mimula* and *Bembicium auratum*, were small and lived among the complex structure provided by the shells of the oysters. They too may be unaffected by any differences in physical conditions around the pylons. Alternatively, the oyster-shells may provide a refuge for the gastropods from larger scale variations in physical phenomena, analogous to that provided by crevices in some other studies (e.g. Levings and Garrity 1983; Fairweather *et al.* 1984; Fairweather 1988).

Littoraria articulata was the exception to this trend; individuals were present in reduced numbers on the southern faces of pylons compared with their northern faces. Gastropods have been shown to behave differently under differing degrees of exposure to waves. For example, Richardson and Brown (1990) found that whelks on exposed shores consumed smaller oysters than those on sheltered shores. Research on tropical rocky shores has shown that levels of insolation can be an important factor determining the patterns of distribution of intertidal molluscs (Garrity and Levings 1981; Garrity 1984; Williams 1994). On one pylon (11a), the northern side is under the jetty and would therefore be more shaded than the southern side, but for the other (12b), the north face is exposed to the sun throughout the day. This would seem to rule out insolation as a causative factor. Since the prevailing winds are from a southerly direction, differences in exposure to waves could play a role. The patterns were not repeated on the landward pylons sampled.

The population of *Bembicium auratum* was unusual because no individuals were larger than 4 mm. In populations studied near Sydney, reproductive maturity was not attained until a size of at least 10 mm had been reached (Muggeridge 1979). There are two possible explanations for the pattern seen at Mandorah: either the individuals represented a sub-population (or subspecies) that attains sexual maturity at smaller sizes or they were not sexually mature. If the individuals are indeed immature *B. auratum*, they may have been recruited from another population for the first time that year or arrive regularly, but never survive to grow larger than 4 mm.

The large rock-platform adjacent to the jetty did not support a similar assemblage to that described for the jetty. In fact, the surface was relatively bare and life appeared to be concentrated under boulders and in pools (pers. obs.). Why do the pylons of the jetty contrast with this pattern by supporting such a complete cover of oysters and associated gastropods on their exposed surfaces? Garrity and Levings (1981) observed that oysters were rare on horizontal surfaces but abundant on vertical surfaces in Panama Bay. Garrity (1984) suggested that vertical surfaces offer a milder physical environment in terms of heat stress than do horizontal ones. In addition, the walkway supported by the pylons shades them during the hottest part of the day. Another difference between the jetty and the adjacent shore is the level of sedimentation. The rocky platform is patchily covered with a layer of fine sediments. Such sediments could bury oysters periodically, preventing them from becoming established. The vertical pylons of the jetty may provide a refuge from siltation and other physical stresses. Biological factors, such as differential recruitment or predation, could also be important. Appropriate tests would be necessary to distinguish between them.

For whatever reason, the pylons support an assemblage that is taxonomically distinct from that found on other hard substrata nearby. Populations occupying the surfaces of the jetty may act as a pool of reproductive adults supplying recruits to suitable substrata elsewhere in the Harbour. The pylons may therefore play a role in maintaining the biodiversity of Darwin Harbour. In addition, Bailey-Brock (1989) discussed the value of artificial substrata as sources of food and habitat for fish, with resultant benefits to nearby fisheries.

The role of secondary substrata in maintaining diversity has been emphasised by Lohse (1993). Here, a variety of species of gastropods was found among oysters. It is clear that the oysters provide suitable microhabitat for *Patelloida mimula* (see below) and may also be important to the other gastropods. Anything that causes a reduction in the cover of oysters on the jetty may consequently affect the assemblage as a whole. It is interesting to note, however, that at least for *P. mimula*, dead oysters are, if anything, more valuable as microhabitat than live oysters (see below). The relatively great incidence of dead oyster shells at the landward end of the jetty was not accompanied by a reduction in the numbers of other species. The difference in mortality of oysters seems most likely to be explained by differences in accessibility to casual human foragers. Foraging which only removes the upper valves of oysters does not seem to pose a serious threat to the populations of epibiotic gastropods.

Epibiosis of *Patelloida mimula*. The correlation with oysters, although significant, was not as strong as might be expected given the rarity of limpets on primary substratum (pers. obs.). The reason for this may be found in the relatively small densities of the limpets in relation to the size of quadrat used. The small numbers of limpets per quadrat meant that even quadrats with little cover of oysters could contain the maximal number of limpets recorded without any limpets being on bare concrete.

In general, the rates of dispersal of limpets from oysters were quite slow during the period of monitoring. In all groups but one, at least 80% of marked limpets were still on their original hosts after one week and usually the percentage was considerably greater. These rates of dispersal are much slower than those described for limpets living on small (relative to oysters), mobile gastropods (Eikenberry and Wickizer 1964; Mapstone *et al.* 1984). On the other hand, the lifelong associations suggested by Scheibling *et al.* (1991) certainly do not occur in this case. Seasonally prolonged burrowing by hosts (*Batillaria* spp.) imposed a limit on the time spent on them by *Patelloida lampanicola* (Morton 1980). *Patelloida mimula* are not constrained in this way, so an alternative explanation must be sought for the exchange of hosts that gradually takes place.

Branch (1981) asserted that the balance between production of food and metabolic requirements of the limpet can influence the duration of stays by epibionts on individual hosts. Eikenberry and Wickizer (1964) measured consumption of food by *Acmaea asmi* and its production on their hosts (*Tegula funebralis*) and concluded that limpets consume 7% of available algae per hour. This could have necessitated the rapid exchange of hosts that they observed. On the other hand, Branch (1981) found that the production of food on shells of *Oxystele sinensis* exactly supplied the requirements of *Patella longicosta*, enabling associations to persist. Mackay and Underwood (1977) gave experimental evidence that supply of macroalgal food is important in determining proportions of groups of *Cellana tramoserica* homing within or dispersing from areas of rocky shore in New South Wales.

Patelloida mimula were more abundant at any given time on dead than on live oysters (Table 1). This pattern is consistent with that observed in populations near Sydney (Creese 1978; Crowe unpubl. data). Behaviour of limpets was implicated as a cause for this, with tentative support being found for the model that limpets spend more time on dead than on live hosts as they move across the substratum (Fig. 8). This tendency could well be explained in terms of the foraging behaviour of the limpets. To assess the applicability of this model, comparative measurements of biomass of algae on live and dead oysters in the absence of *P. mimula* must be made. If a difference were found, an appropriate test of the model would be to reduce food availability on groups of dead oysters and hypothesise an increased rate of dispersal of limpets from these oysters relative to controls.

Lindberg (1990) coined the term 'carbonate association' to describe relationships between limpets and hosts that were previously considered to be commensal. At least one of the 'carbonate associates' he mentioned, *Patelloida mufria*, is selective about which of the available carbonate substrata it lives on - it occurred more frequently on *Austrocochlea constricta* than on other species (Mapstone *et al.* 1984). Moreover, the limpets were more likely to be found under the basal body-whorl than elsewhere on the shell. The protection afforded by this position, combined with the fact that *P. mufria* was more likely to stay on *Austrocochlea* that remained in pools than on those that left them, led the authors to propose avoidance of desiccation as one of the factors likely to promote the association. Similarly, Morton (1980) found that *Patelloida lampanicola* typically attached to the body-whorl and were uncommon on other parts of their hosts (*Batillaria zonalis*). In another 'carbonate association', between *Turbo undulatum* and coralline algae, Worthington and Fairweather (1989) found that snails (a) ate the algae and (b) would remain aggregated around scouring brushes that mimicked its structure. In the present study, limpets were more frequently associated with dead oysters than live oysters. In all these cases, the specificity of the requirements of the epibiont suggest that the mere presence of carbonate is not the factor inducing the association. The important features of host organisms – nutritional value, structural complexity and behaviour – are consequences of the biotic nature of the 'carbonate' in question and are quite specific. To lump such interactions under the term 'carbonate association' is to ignore the often complex nature of the relationships in question.

CONCLUSIONS

There are two ways in which patterns described in the current study could be construed as conforming to the general latitudinal trends identified by Lubchenco *et al.* (1984), by comparing data from Taboguilla Island (Panama) with that from studies of temperate locations. First, there was little variation in community structure between sites (pylons) and between landward and seaward areas. Second, the zones of vertical distribution could arguably be described as 'indistinct' (a phenomenon also considered typically tropical by Menge and Lubchenco (1981)), in that there were considerable areas of overlap between (a) barnacles and oysters and (b) epibiotic grazers and epibiotic algae (Fig. 5).

I would argue, however, that restraint should be exercised in attempting to draw latitudinal generalities from comparisons involving only a few tropical studies at even fewer sites (Menge and Lubchenco 1981; Lubchenco *et al.* 1984). Although the recent study adds to the sparse data on tropical habitats and is useful in that respect, such a piecemeal approach can ultimately yield 'only glimpses of the similarities and differences among localities' (Underwood and Petraitis 1993). Brosnan (1992) also discussed the way that the relative importance of processes structuring communities may change with latitude. It has, however, yet to be demonstrated that such changes can be reliably predicted on the basis of latitude alone. McGuinness (1990) pointed out the substantial variation of physical conditions and assemblages present within a small radius of the Taboguilla site studied by Lubchenco *et al.* (1984). In fact, they themselves pointed out that intensity of predation, considered so pivotal in structuring the community at their site, was considerably reduced at more exposed sites nearby. Underwood and Fairweather (1986) also contributed to this debate by considering the problems inherent in comparing the ecology of different locations using studies done by different researchers. Underwood and Petraitis (1993) stressed the need for properly replicated comparative studies at a number of sites, carefully stratified to take account of variation at a number of spatial scales.

The present study constitutes a first step in the study of the assemblage inhabiting the jetty. It underlines the need to consider the potential for variation at a range of spatial scales before embarking on more detailed consideration of mechanistic processes. The observed patterns provide starting points for many avenues of further research. The data may also prove useful as a baseline against which to measure temporal changes in abundance of epifaunal molluscs in Darwin Harbour.

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THE DISTRIBUTION OF *TEREBRALIA PALUSTRIS* (LINNE) WITH RESPECT TO MICROHABITAT IN MANGROVE FORESTS OF DARWIN HARBOUR I: DESCRIPTION OF PATTERNS.

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ABSTRACT

In the first of two related papers, small-scale patterns of distribution of the mud whelk, *Terebralia palustris*, sampled in replicate transects at each of two sites in Darwin Harbour, are described. The abundance of *T. palustris* was positively correlated with (a) percentage cover of canopy of mangrove trees (in three of the four transects sampled) and (b) percentage cover of leaf litter (in all four transects). No correlation was found between the distribution of *T. palustris* and percentage cover of surface moisture.

Keywords: *Terebralia*, microhabitat, mangroves, ecology, Darwin Harbour, correlation.

INTRODUCTION

Microhabitat has long been recognised as an important factor determining patterns of distribution of species and their ecological interactions (e.g. Andrewartha and Birch 1954; Krebs 1972; Rutt *et al.* 1989). Knowledge of a species' relationship to microhabitat can greatly facilitate the prediction of its spatial distribution, the effect that alterations to habitat may have on its abundance and its movement across a landscape (Buckland and Elston 1993). The association of species with particular microhabitats can also affect other members of the assemblage. For example, Levings and Garrity (1983) studied the use of crevices as refugia by grazing nerites. They observed that crustose algae were absent near crevices, but were abundant less than a metre away (commonly called the 'halo pattern'). Blocking crevices to exclude the grazers resulted in the growth of algae on adjacent rock. Many researchers, including Underwood (1976), Leviten and Kohn (1980) and Chapman (1994), have confirmed the importance of microhabitat to marine molluscs.

Mudwhelks (family Potamididae) occur in mangrove forests throughout the Indo-west Pacific. They live on the surface of sediments at a range of heights on the shore (Plaziat 1984). *Terebralia palustris* is the largest member of the family and the most widely distributed (Houbrick 1991). It reaches a maximal recorded size of 190 mm (Loch 1987) and may occur in densities of up to 150 per m^2 (Plaziat 1984). There are very few recent studies of its ecology (Plaziat 1977; Soemodihardjo and Kastoro 1977; Wells 1980; Nishihira 1983; Shokita *et al.* 1984; Rambabu *et al.* 1987). Prior to this study, there has been only one quantitative description of its relationship to microhabitat (Wells 1980). Populations of potamidids (including *T. palustris*) have been recorded in surveys at several sites in Darwin Harbour (Hanley 1993a) and the McArthur River (Hanley 1993b), but to date no study has examined small-scale patterns of distribution or included experimental tests of models that may explain those patterns.

Wells (1980) found that patterns of distribution of *T. palustris*, and its congener, *T. sulcata* (reclassified as *T. semistriata* (Houbrick 1991)),

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could be related to the floristic composition of the mangroves in the Bay of Rest, Western Australia. The mudwhelks occurred at characteristic heights on the shore but were not found in areas dominated by *Rhizophora stylosa*. Hanley (1993b) found no association between *T. palustris* and particular species of mangrove in the McArthur River system. *Terebralia palustris* at the Mandorah site of the current study (see Methods) appeared to be clustered under both *Avicennia marina* and *Rhizophora stylosa* and to be rare in areas lacking canopy (pers. obs.).

Plaziat (1977, 1984) and Nishihira (1983) have both observed the consumption of fallen leaves by adult *T. palustris*. In addition, Rambabu *et al.* (1987) used laboratory experimentation to infer a preference by *T. palustris* for sediments containing plant material. Finally, previous workers have observed an association between *T. palustris* and pools of water (MacNae 1968; Wells 1980; Hanley 1993b). Initial observations at Mandorah, however, suggested that *T. palustris* were not associated with water.

This study focussed on small-scale patterns of distribution within areas where the animals were relatively abundant. The aim was to characterise aspects of the microhabitat in which individuals were most commonly found. It was hypothesised that there would be a positive correlation between abundance of *T. palustris* and percentage cover of mangrove canopy. The species of mangrove present were also noted and related to the abundance of mudwhelks. Based on the observations of the diet of *T. palustris* mentioned above, it was predicted that the quantity of leaf litter present in a quadrat would correlate positively with numbers of *T. palustris*. It was hypothesised that this pattern might be particularly evident where leaves were scarce and thus potentially limiting. The cover of water was also measured and correlated with densities of *T. palustris*.

METHODS

The distribution of *Terebralia palustris* and features of the microhabitat were sampled at two sites at which *T. palustris* was relatively common. The sites were as follows.

1. Mandorah: located near the bank of a small creek about 1.5 km south of Mandorah Beach Resort at the entrance to Wood's Inlet, Darwin Harbour, Northern Territory (12° 27' 24" S, 30° 45' 46" E), (Appendix to proceedings.), the site was high on the shore and had mixed, patchy cover of *Avicennia marina* and *Rhizophora stylosa* trees.

2. Hudson Creek: this site was near the north bank of a drainage channel flowing into Hudson Creek about 400 m east of the Trade Development Zone complex on Berrimah Road (12° 28' 04" S, 130° 55' 49" E). The site was in mangrove forest dominated by *Ceriops australis* interspersed with *Aegialitis annulata* as well as occasional specimens of *A. marina*.

Two adjacent transects were sampled at each site. At Mandorah, the transects each comprised 43 quadrats of dimensions 0.25 x 0.25 m laid contiguously along a tape approximately parallel to the sea and perpendicular to the nearby creek (bearing: 142°). At Hudson Creek, *Terebralia* were less densely distributed, so larger quadrats (0.5 x 0.5 m) were used. Twenty-five contiguous quadrats were sampled per transect. The bearing was 20°, again perpendicular to the creek but parallel to the main body of water into which it flowed, in this case Hudson Creek.

In each quadrat, the number of *T. palustris* was recorded as well as the following variables describing the microhabitat.

(a) Surface moisture: an approximate estimate was made of the percentage of the area covered by water >0.5 cm deep.

(b) Leaf litter: different systems were employed to estimate abundance of leaf litter at the two sites. At Hudson Creek, fallen leaves covered a substantial proportion of the substratum, so an approximate visual estimate of total percentage cover was made. At Mandorah, there was typically less than 10% cover of leaves on the substratum. Since *T. palustris* may eat leaves (see Introduction), the presence of even a few could be important to the snails. Subjective estimation of percentage cover would not have been a sufficiently sensitive measure to document differences between quadrats. Instead, a 'standard leaf unit' (5 x 1.5 cm approx.), was defined and the number of 'standard leaf units' present in each quadrat was counted.

(c) Vegetation: for each species of mangrove present, a note was made of (i) roots: percentage cover of prop-roots or pneumatophores as applicable, (ii) trunks: the number of trunks of *Avicennia*, *Aegialitis* or *Ceriops*.

(d) Total canopy cover: an estimate was made of the percentage of the quadrat lying vertically beneath the canopy of mangrove trees.

For each transect, the relationships between distribution of *T. palustris* and each of (a) total canopy, (b) leaf litter and (c) surface moisture

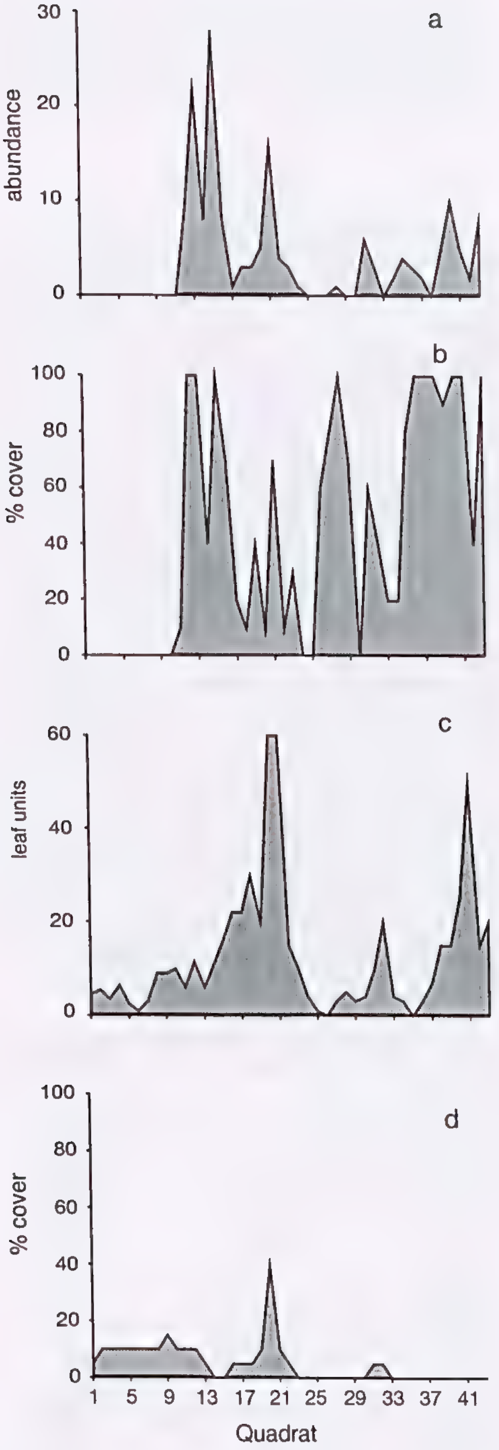

Fig 1. Mandorah, Transect a. (**a**) abundance of *T. palustris*, (**b**) percentage cover of canopy of mangrove trees, (**c**) area covered by leaf litter (measured in "standard leaf units" - see text for details), (**d**) percentage cover of surface moisture.

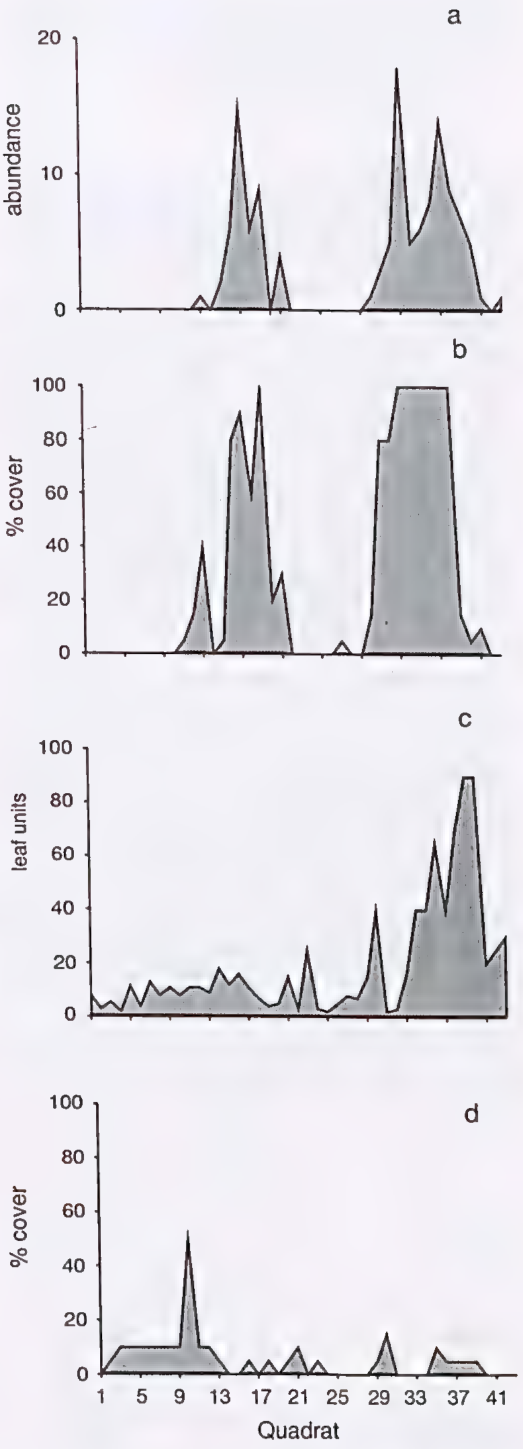

Fig 2. Mandorah, Transect b. (**a**) abundance of *T. palustris*, (**b**) percentage cover of canopy of mangrove trees, (**c**) area covered by leaf litter (measured in "standard leaf units" - see text for details), (**d**) percentage cover of surface moisture.

were evaluated using product-moment correlation. In addition, coefficients of correlation between canopy and leaf litter were calculated.

RESULTS

Terebralia palustris was considerably more abundant in the transects at Mandorah (mean density = 53 m^{-2}) than at Hudson Creek (mean density = 13 m^{-2}). At Mandorah, the transects sampled areas with a patchy cover of mangrove canopy (Figs 1-2). *Terebralia palustris* was never found in quadrats that had no cover of mangrove canopy. In both transects, there were significant positive correlations between abundance of *T. palustris* and percentage cover of canopy (Table 1, Fig. 3). All quadrats sampled at Hudson Creek had some cover of mangrove canopy. This varied from 15 to 100% (Figs 4-5). Positive relationships between abundance of *T. palustris* and percentage cover of canopy were found to be significant in transect a but not in transect b (Table 1, Fig. 3).

Abundance of *T. palustris* increased with increasing percentage cover of leaf litter in all transects (Table 1, Fig. 3). It was hypothesised that these correlations could have arisen because of a relationship between abundance of leaf litter and cover of mangrove canopy (which was also correlated with abundance of *T. palustris*). Correlations between leaf litter and canopy were non-significant at Mandorah, but significant at Hudson Creek (Table 1). In three of the four transects, correlations with leaf litter explained less of the variance in the *T. palustris* data than did canopy (see r^2, Table 1).

There was no significant relationship between *T. palustris* and surface moisture in any transect (Table 1, Fig. 3).

DISCUSSION

The distribution of *Terebralia palustris* was related to cover of (a) mangrove canopy and (b) leaf litter. At Hudson Creek, the canopy was almost continuous, making it hard to resolve its importance in predicting the distribution of mudwhelks. This may explain why there was a non-significant correlation at one of the transects at Hudson Creek. Nevertheless, all four correlations between *T. palustris* and canopy were positive and three of them were significantly so ($P<0.001$). It is extremely unlikely that such a result could have occurred by chance.

Positive relationships between *T. palustris* and leaf litter were found at Mandorah despite the small quantities of leaf material present. This suggests that the relationship between *T. palustris* and leaves may be an intimate one. Along three of the four transects, however, canopy explained more of the variance in the data for *T. palustris* than did leaf litter, implying that the relationship between canopy and *T. palustris* is stronger than that between leaf litter and *T. palustris*. In Hudson b, the canopy effectively covered the entire transect and *T. palustris* were widely distributed. In this instance, leaf litter was a better predictor of abundance of

Table 1. Correlation between *T. palustris* and variables of microhabitat (rows 1-3) and between leaf litter and canopy cover (row 4). See text for explanation of data collected. (H_0: $r = 0$, tested by t-test with 41 df at Mandorah and 23 df at Hudson Creek. 'ns' denotes results not significant at $P<0.05$).

	Transect Variable	Mandorah a	Mandorah b	Hudson a	Hudson b
Canopy	r	0.53	0.83	0.65	0.35
	P	<0.001	<0.001	<0.001	ns
	r^2	0.29	0.69	0.42	0.12
Leaf litter	r	0.37	0.38	0.61	0.49
	P	<0.05	<0.05	<0.01	<0.05
	r^2	0.14	0.14	0.37	0.25
Surface moisture	r	-0.05	-0.19	-0.16	-0.02
	P	ns	ns	ns	ns
	r^2	0.002	0.04	0.03	0.0005
Leaf litter vs. Canopy	r	0.19	0.27	0.49	0.49
	P	ns	ns	<0.05	<0.05
	r^2	0.04	0.07	0.24	0.24

T. palustris. Although patterns of association between *T. palustris*, canopy and leaf litter are clearly apparent, it is not yet possible to characterise the interrelationship between the three variables (see below).

In contrast to the findings of Wells (1980) and Hanley (1993b), there was no association of *T. palustris* with surface moisture. There are several possible reasons for this. One explanation could be that the surface water in the present

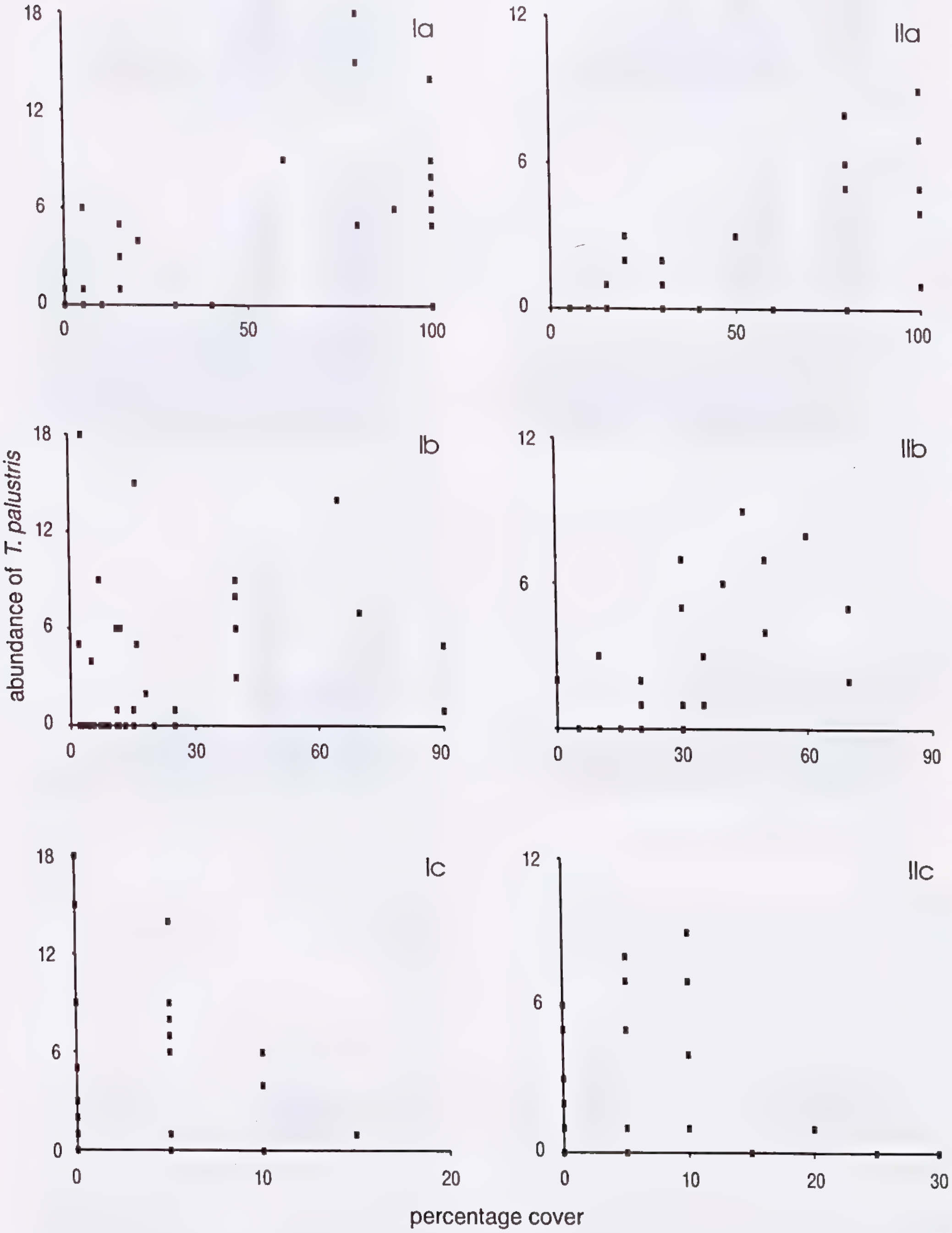

Fig 3. Examples of relationships between abundance of *T. palustris* and percentage cover of (a) canopy, (b) leaf litter and (c) surface moisture. **I** - Mandorah, transect a and **II** - Hudson's Creek, transect b. Correlation coefficients are presented in Table 1.

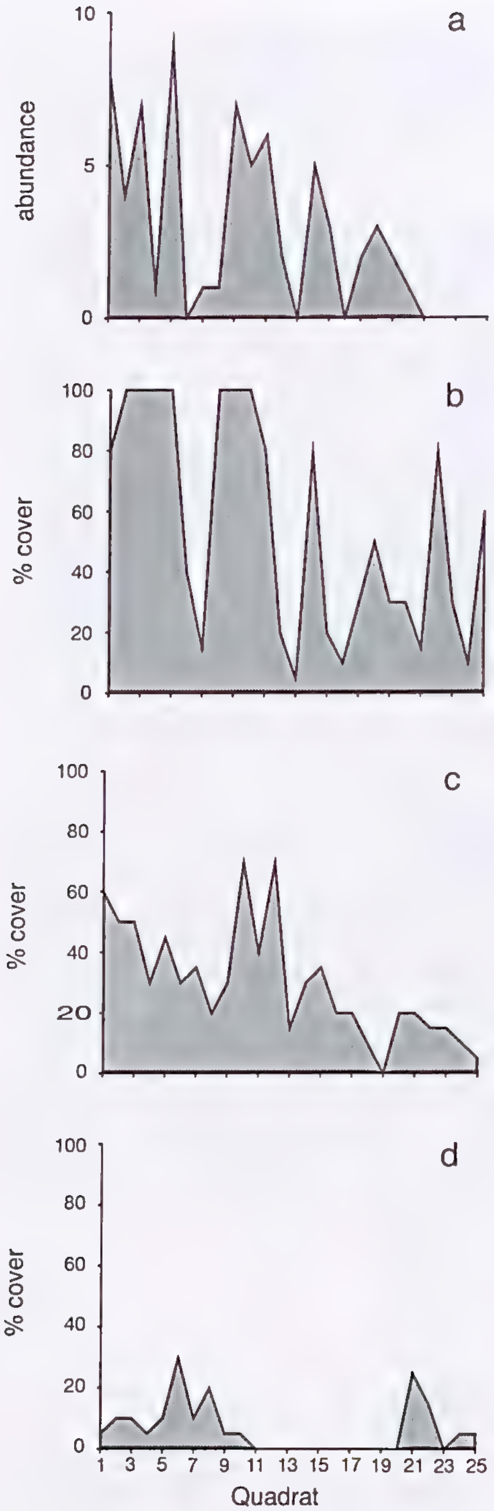

Fig 4. Hudson Creek, Transect a. (**a**) abundance of *T. palustris*, (**b**) percentage cover of canopy of mangrove trees, (**c**) percentage cover of leaf litter, (**d**) percentage cover of surface moisture.

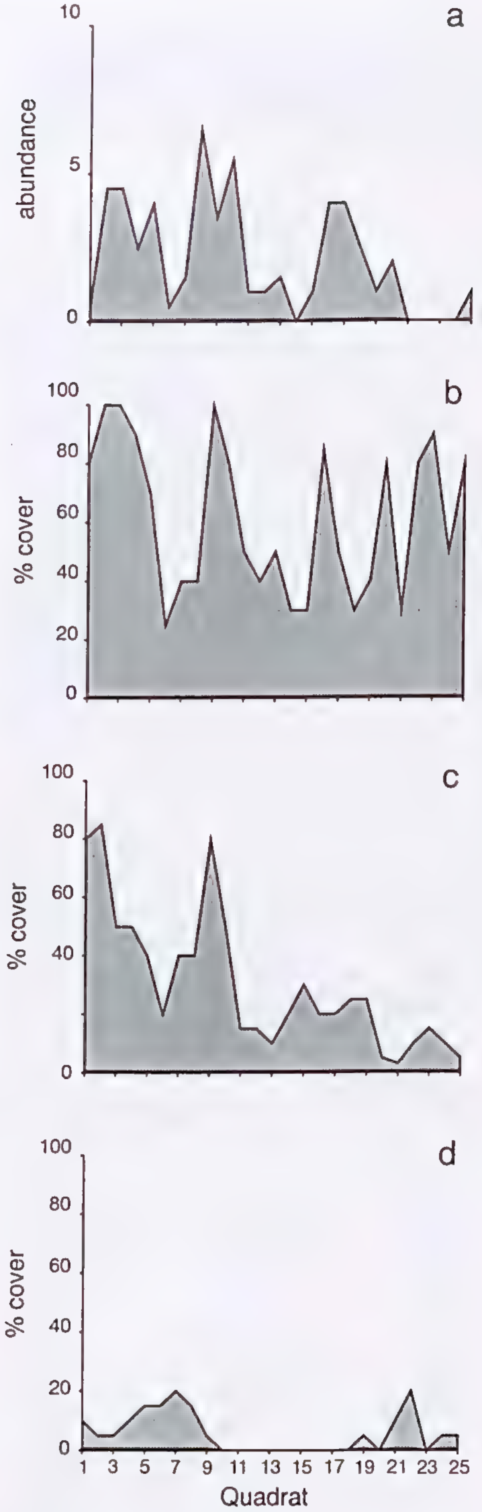

Fig 5. Hudson Creek, Transect b. (**a**) abundance of *T. palustris*, (**b**) percentage cover of canopy of mangrove trees, (**c**) percentage cover of leaf litter, (**d**) percentage cover of surface moisture.

study differed somehow from that present in the previous studies. For example, at Mandorah the water was quite shallow (< 2 cm) and at Hudson Creek it was flowing (albeit slowly). The pools in the McArthur were typically 2-5 cm deep and still (R. Hanley, pers. comm.), whereas those in the Bay of Rest were of similar depth to those in the transects at Mandorah, but may have differed in some aspect of water quality (F. Wells, pers. comm.). In addition, the climate in the Bay of Rest (and in the Pilbara region generally) is arid and the distribution of *T. palustris* is more restricted there than in Darwin (F. Wells, pers. comm.). Casual observations at Mandorah suggested that large pools of water were more or less exclusively occupied by *Telescopium telescopium* (another member of the family Potamididae). One feasible model to account for the distribution of *T. palustris* in the mangroves of Darwin Harbour is that when the two species co-occur, *T. palustris* changes its behaviour with respect to water. Further sampling (and ultimately experimentation) at larger spatial scales would be needed to examine such a model.

The focus in the present study was on small-scale patterns of distribution of *T. palustris*. Sites were chosen within areas in which *T. palustris* was the dominant potamidid. For this reason, it would have been misleading to consider abundances of other species of potamidid, such as *T. sulcata*, *T. semistriata* and *Telescopium telescopium*. Wells (1980), in a large-scale study of the Bay of Rest (Western Australia), found that patterns of distribution of *T. sulcata* and *T. palustris* could be distinguished in terms of height on the shore and the sizes of particles in the substratum. It would be of value to sample potamidids in conjunction with these variables, as well as those found to be important in the present study, over broad spatial-scales in Darwin Harbour. Such data would provide a useful test of the effectiveness of these variables in predicting broad-scale patterns of distribution of mud whelks.

As with all correlational studies, the interpretation of these results in mechanistic terms is not straightforward. At this stage, it is not logically possible to separate or characterise the influences of the canopy, leaf litter and snails on each other. The possibility also exists that some other factor, as yet unmeasured, is influencing the trees, leaf litter and snails simultaneously and causing their patterns of distribution to coincide.

One way to attempt to resolve the latter dilemma is to further analyse the data in order to separate out the effect of unmeasured variables associated with the spatial arrangement of the data. This is done either by 'prewhitening' (Student 1914; Haugh 1976), by partialling out spatial variation (Borcard *et al.* 1992; Leduc *et al.* 1992; Legendre and Trousellier 1988) or by modifying tests of significance of the observed correlations (Clifford *et al.* 1989; Dutilleul 1993). Spurious relationships caused only by the influence of other variables (e.g. space) may sometimes be distinguished from those that are caused by a real interaction between the observed variables. While potentially producing a less misleading picture, these approaches can never unequivocally eliminate any of the possible explanations for the observed patterns. Another approach to disentangling the causal mechanisms underlying the pattern is to propose logically distinct models and to test them experimentally. This approach is widely accepted as a powerful and incisive tool for exploring causality in ecology (e.g. Connell 1961; Paine 1974; Underwood 1985, 1990, 1991; Lubchenco and Real 1991). Experimental manipulations, if properly planned and executed (see Underwood 1981; Hurlbert 1984) enable the researcher to separate the effects of coincidental spatial variables from those of the factor under investigation. An experimental test of one model to explain the observed patterns of distribution of *T. palustris* with respect to microhabitat is presented in a companion paper (Crowe and McMahon 1997).

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THE DISTRIBUTION OF *TEREBRALIA PALUSTRIS* (LINNE) WITH RESPECT TO MICROHABITAT IN MANGROVE FORESTS OF DARWIN HARBOUR II: EXPERIMENTAL EVALUATION OF BEHAVIOUR.

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ABSTRACT

The mud whelk *Terebralia palustris* occurs in greater numbers beneath the canopy of mangrove trees than on areas of exposed mud between trees. An experiment was done to test the model that the behaviour of adult *T. palustris* could account for the observed pattern. Individuals placed on exposed mud moved rapidly back to resting sites beneath the canopy. Control animals that were moved within and between plots under trees were more likely to stay *in situ*.

KEYWORDS: *Terebralia*, microhabitat, experiment, mangroves, ecology, Darwin Harbour.

INTRODUCTION

It is often assumed that, because individuals of a species are more abundant within a particular microhabitat, they 'prefer' to be there. In other words, adults are assumed to actively seek out that microhabitat (e.g. Barnes and Greenwood 1978; Orth and Maughan 1983; Teague *et al.* 1985). In fact there are three broad models that could explain such a pattern. The first is settlement / recruitment: larval or juvenile individuals could recruit in greater numbers to that microhabitat than to others and not subsequently leave. The second alternative is that the population distributes itself randomly throughout the available habitat, but differential mortality leads to the reduction of numbers in the 'unfavourable' microhabitats. The last possibility is that after widespread recruitment, individuals exhibit behaviour that causes an association with the 'favoured' microhabitat (Underwood 1979; Underwood and Denley 1984).

To understand patterns of distribution, it is necessary to decide, by appropriate test, which model or combination of models applies. Subsequent, more detailed, investigation of processes affecting distribution and abundance will be determined, to a large extent, by the results of such a test. For example, if differential mortality is found to be the dominant cause of the pattern, it would be necessary to distinguish between explanatory models such as predation or physical stress. On the other hand, a pattern of distribution with respect to microhabitat that depends on recruitment would require the investigation of factors affecting juveniles and their dispersal. These factors may be entirely distinct from those affecting adults. This is especially true for marine benthic invertebrates with pelagic larval stages.

In the first part of this study, it was found that *Terebralia palustris* occurs at greater densities under mangrove trees than on patches of open space between trees (Crowe 1997). In addition to the models discussed above, the possibility was also raised that the patterns of distribution of the species and its microhabitat coincide under the influence of other, unmeasured factors.

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The present experiment was designed to test the model that the behaviour of adult *T. palustris* could account for the observed pattern of distribution with respect to mangrove canopy. It was predicted that, if groups of snails were transplanted to areas of open mud, a greater proportion of them would disperse compared to groups of control animals moved in an area under trees. Furthermore, it was predicted that they would move to areas under trees and would be found there in greater numbers than expected by chance at the end of the experiment.

Previous researchers have shown that distances and directions of movements of snails are sometimes altered by experimental manipulations (Petraitis 1982; Chapman 1986, 1992; Underwood and Chapman 1994). These variables were also measured and analysed.

MATERIALS AND METHODS

The study location was near the bank of a small creek about 1.5 km south of Mandorah Beach Resort at the entrance to Wood's Inlet, Darwin Harbour, Northern Territory (12°27'24"S, 30°45'46"E). (Appendix to proceedings) This location was named 'Mandorah' in the first part of this study (Crowe 1997).

Two sites were marked out at that location. Both sites were high on the shore and had mixed, patchy cover of *Avicennia* and *Rhizophora* trees. On 19 July, 1993, twelve trees were selected at each site. Each had at least 15 adult *Terebralia palustris* within 30 cm of its trunk. Three trees were randomly assigned to each of four treatments: (1) transplantation - experimental, (2) translocation - controls for the effect of moving individuals to an unfamiliar area, (3) disturbance - controls for the effect of handling the snails without any change of location and (4) undisturbed - represents the natural population of untouched snails (Chapman 1986; Underwood 1986, 1988; Chapman and Underwood 1992).

In treatments one, two and three, fifteen snails from each replicate tree were removed, marked individually with enamel paint and left for fifteen minutes to allow the paint to dry. (1) The groups assigned to be transplanted were placed within a 0.5 m radius of a marker stake positioned no more than 3 m from their tree of origin and approximately 1.5 m from the trunk of the nearest tree. (2) The groups of snails to be translocated were placed within 0.5 m of the trunks of trees no more than 3 m away from their tree of origin. Fifteen snails had previously been removed from the area under the new tree to guard against any possible effect due to increased density. (3) After being handled in the same way as those in treatments one and two, the snails in the 'disturbed' treatment were replaced under their original trees. (4) The snails in the undisturbed treatment were not handled at all, but were marked *in situ* under their trees. There was no control for the effect of the paint itself because unpainted snails would be indistinguishable from the remainder of the population.

The snails were left for two days and then a search was made for the marked snails. Those that were still within 0.5 m of the marker or tree trunk were considered to have remained in the plot in which they had been placed. Each group of fifteen snails represented one replicate in an analysis of variance for which the data were the proportions of individuals remaining in experimental plots at the time of monitoring.

For each individual found outside the plot, its displaced distance and compass-bearing from its plot-marker or tree trunk were measured. Animals that were found within the plot were considered to have moved 0 cm. Because a minimum of 13 individuals was recovered from any given plot, analyses of the displacement from each plot were done using 13 randomly selected individuals from each plot.

The displaced distances were analysed by analysis of variance. It was not possible to stabilise the variance in the measurements of distance by log transformation; however, Box (1953) and Underwood (1981) have suggested that analysis of variance is robust with regard to variance heterogeneity. This is especially true where the numbers of treatments and replicates are sufficiently large and the design is balanced, as in this case.

The directions in which the snails travelled were analysed using circular statistics. For each group of snails the average resultant ($\bar{R}$) was calculated. This statistic is a measure of the degree to which the individuals in the group moved in a uniform direction. $\bar{R}$ is a value between zero and one, where a value of one is obtained if all individuals moved in the same direction, and the result approaches zero as the orientations of movement become increasingly random and there is no common directionality (Batschele 1981).

Previous studies have shown that movements of groups of gastropods may become more directional after experimental transplantation to habitats in which they are not usually found (Chapman 1986). In some cases, this response has also been also found in groups of individuals that have simply been translocated or disturbed (Petraitis 1982; Chapman 1992). It is important to determine whether any observed directionality is part of a reaction to the new habitat, merely a response to experimental manipulation *per se*, or part of the normal behaviour of the animals. The directionality of the groups of snails in the different treatments was compared to test the hypothesis that groups of transplanted snails would move with greater directionality than controls.

The area occupied at the study location by different types of microhabitat was measured in transects of contiguous quadrats in the first part of this study (Crowe 1997). These estimates were used in two chi-squared goodness of fit analyses that tested the null hypothesis that the experimentally manipulated *Terebralia palustris* moved into microhabitats in proportion to the amounts present in the habitat. The analyses were of the distribution of experimental snails in relation to (a) open space and (b) mangrove canopy.

It was expected that some of the individuals found outside the canopy of the mangrove would be associated with related features of microhabitat, such as shade, plant structures (e.g. pneumatophores) and leaves. The microhabitat in which each individual had come to rest was characterised using the following descriptors: (i) open mud, (ii) within 1 cm of a fallen leaf, (iii) touching a pneumatophore of *Avicennia sp*., (iv) in water deeper than 0.5 cm. (v) vertically beneath mangrove canopy, (vi) shaded, (vii) within 5 cm of a trunk of *Avicennia* or a prop-root of *Rhizophora*.

RESULTS

Dispersal of *T. palustris* from experimental plots. Of the 360 snails that were painted, a total of 344 was found. The average rate of retrieval of snails from a treatment at a site was 43 out of 45 snails (95.56%, SE = 6.72%), with a maximal loss in any one treatment of three individuals. These individuals had either been removed (e.g. by predators) or had moved to a distant or cryptic resting place. The loss of such small numbers of individuals could have very little effect on the overall results, especially given that losses were so uniform between treatments.

A significantly greater proportion of snails dispersed from plots in the transplantation treatment than from all control groups ($p<0.01$) (Table 1; Fig. 1). Among the control treatments, translocated animals were more likely to disperse than were disturbed or undisturbed individuals ($p<0.05$). Dispersal of individuals that had been handled during painting was not different from those painted *in situ*. These results were consistent at the two sites.

Distance and directionality of movement. Transplanted snails moved significantly further on average than did snails in the control treatments ($p< 0.05$) (Table 2; Fig. 2). Control ani-

Table 1. Analysis of numbers of *Terebralia palustris* remaining in experimental plots. Each replicate is the proportion of a group of 15 individuals found within 0.5 m of the centre of the plot in which it started ($n = 3$; data are untransformed; Cochran's test: ns).

(a) Analysis of variance.

Source of variation	df	MS	F	*P*
Site = S	1	0.00	0.00	>0.99
Treatment = T	3	0.32	59.73	<0.005
S x T	6	0.01	0.27	>0.85
Residual	16	0.02		

(b) SNK test on treatment means (horizontal lines underlie means that are not significantly different; ** $p<0.01$; * $p<0.05$).

Treatment	Transplanted	Translocated	Disturbed	Undisturbed
Mean	**0.044	*0.32	0.48	0.58
SE	0.022	0.04	0.06	0.07

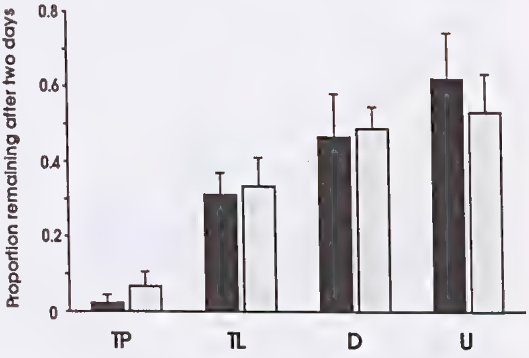

Fig. 1. Mean (+SE) proportion of *Terebralia palustris* (15 individuals) remaining in the plot after 2 days. $n = 3$ (TP = transplanted, TL = translocated, D = disturbed, U = undisturbed, ■ = Site I, □ = Site II).

mals moved similar distances regardless of whether they had been translocated, disturbed or painted *in situ*. There was considerable variation among plots (p<0.001, Table 2a). This is particularly evident among plots of transplanted snails at Site II (Fig. 2). The mean distances moved were not different between sites.

The statistical significance of the directionality of a set of data is dependent on the number of measurements used to calculate $\bar{R}$ and is only testable for groups of five or more individuals (Batschelet 1981). This meant that for Site I it was only possible to calculate and test $\bar{R}$ for two plots in each treatment. At Site II, three values of $\bar{R}$ were calculated for each treatment. For nine of the 20 groups of snails tested, the null hypothesis of random orientation was rejected (p<0.05), but there was no trend for departure from randomness to be more prevalent in any particular treatment (Table 3).

There are no clear differences in degree of directionality apparent between treatments (Fig. 3). Chapman (1986) presents a method of multifactorial analysis of directionality. In order to balance the design for a formal analysis, however, it would have been necessary to reduce n for each plot to the lowest common denominator, i.e. five. Since this would entail such a loss of data as to render the analysis meaningless, no analysis was done.

Distribution with respect to microhabitat. Although 344 animals were retrieved at the end of the experiment, details of microhabitat were recorded for only 336 due to time-limits imposed by the incoming tide. Open mud comprised approximately 40% of the study area but only 13.7% of snails in the experiment were found on open mud after two days. Conversely, the canopy of mangroves covered approximately one third of the area, but over three quarters of the experimental snails moved to resting sites beneath it. In both chi-square analyses, the null hypothesis of random distribution with respect to microhabitat (relative to its availability) was rejected (p<0.001) (Table 4).

Two hundred and thirty out of 250 (92%) control animals which had been placed under canopy at the beginning of the experiment were found there at its end. Of the other 20, 12 (4.8%) had moved into positions on open mud. The other eight were found either in the shade or close to pneumatophores or leaves.

The experimental animals were placed in areas of open mud at the beginning of the experiment. After two days, details of microhabitat were recorded for 86 of them. Their distribution with respect to microhabitat had become very similar to that of control animals (Figs 4a-b). Sixty (69.8%) were under canopy, 10 (11.6%) were either shaded or close to pneumatophores or leaves and 16 (18.6%) were in exposed positions on the open mud.

DISCUSSION

The results clearly indicate that the behaviour of adult *Terebralia palustris* could account for the observed pattern of distribution. Three lines of evidence support this model. First, a greater proportion of snails transplanted to open mud moved away from their plots than did control animals moved within the microhabitat under the canopy of mangrove trees. Second, the transplanted snails moved greater distances. Finally the greater distances moved by the snails brought them to rest under trees in disproportionately large numbers.

The analyses of directions revealed no consistent differences between treatments in the degree to which individuals moved in a common direction. Petraitis (1982) found that experimental dislodgment of groups of *Littorina littorea* resulted in a change from random to directional movement. Chapman (1986) found no effect of disturbance or translocation on movements of *Littorina unifasciata*. In a later exper-

Table 2. Analysis of displaced distances of *Terebralia palustris* from experimental plots. Distances measured in cm from the centre of the plot (n = 13; data are log transformed; Cochran's test: p < 0.01).

(a) Analysis of variance.

Source of variation	df	MS	F	*P*
Site = S	1	0.06	0.03	>0.87
Treatment = T	3	26.09	18.79	<0.02
Plot = P(S x T)	16	2.14	2.55	<0.001
S x T	3	1.39	0.65	>0.59
Residual	288	0.84		

(b) SNK test on treatment means (transformed to natural logarithms) (horizontal lines underlie means that are not significantly different; * p<0.05).

Treatment	Transplanted	Translocated	Disturbed	Undisturbed
Mean	*4.92	3.99	3.74	3.67
SE	0.05	0.12	0.12	0.12

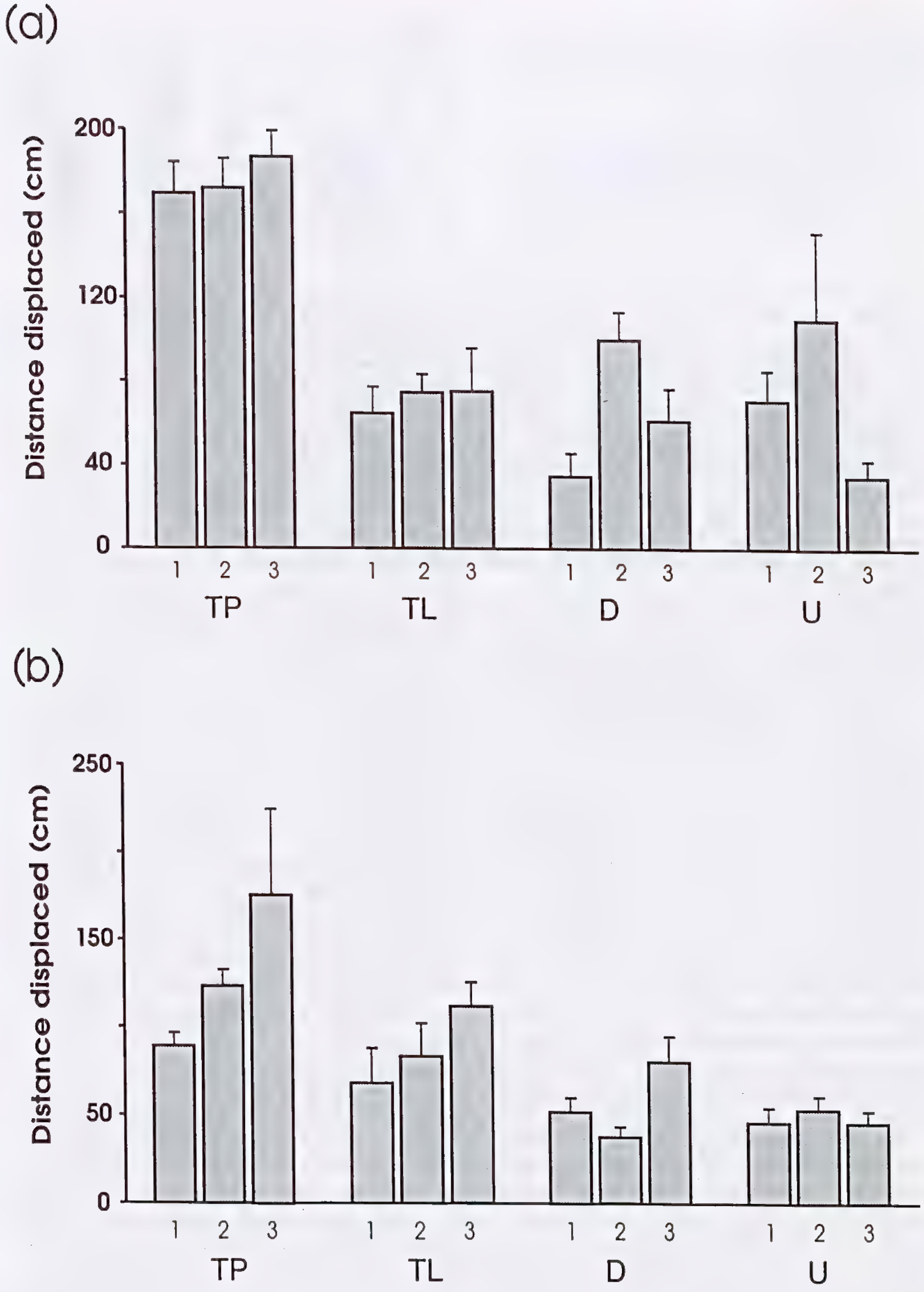

Fig. 2. Mean (+ S.E.) distance displaced from the centre of the plot by each replicate group of snails $n = 13$ **(a)** Site I; **(b)** Site II. (abbreviations as for Fig. 1).

Table 3. Values of Rayleigh's $\overline{R}$ for the groups of experimentally manipulated snails for which five or more directions of movement were recorded. * denotes significant directionality ($p<0.05$). In each case n is given in brackets.

Treatment	Site 1	Site 2
TP	0.35 (14), 0.50* (15)	0.76* (15), 0.35 (15), 0.44 (15)
TL	0.36 (8), 0.19 (9)	0.27 (8), 0.69* (10), 0.59* (12)
D	0.70* (14). 0.89* (7)	0.17 (6), 0.75 (5), 0.39 (7)
U	0.44 (9), 0.66* (7)	0.91*(6), 0.92*(11), 0.56(5)

iment, Chapman (1992) found that the normal foraging movements of a group of *Littorina unifasciata* fitted a random model, whereas groups that have been transplanted to sites lower on the shore tended to move in an upshore direction, as did translocated control groups. In contrast, the movements of undisturbed *Terebralia palustris* were just as likely to show directionality as those that had been disturbed, translocated or transplanted. A similar, but temporally variable, result was found for *Nodilittorina pyramidalis* (Chapman and Underwood 1994).

The animals in treatments one, two and three were placed in clumps at the outset of the current experiment. Chapman (1986) found that, although distances moved were unaffected by the clumping or otherwise of the group, *Littorina unifasciata* showed a greater degree of directionality if they were placed in clumps at the beginning of the trial than if randomly scattered. The undisturbed snails in the current experiment, however, were not dislodged from the aggregations in which they naturally occurred. This suggests that movement in a common direction may be part of the natural behaviour of groups of *T. palustris*. Unlike the populations studied by Petraitis (1982) and Chapman (1992) which lived on inclined surfaces and tended to move upslope, *T. palustris* lives on an almost horizontal substratum, so that gradient cannot provide the cue for orientation of movement. The same was true for the populations of *N. pyramidalis* investigated by Chapman and Underwood (1994). This species exhibited a very constrained distribution with respect to microhabitat. It was only found on patches of pitted rock and experimentally transplanted animals moved rapidly away from areas of smooth rock nearby. Mechanisms promoting commonality of direction of movement may be more highly developed in species whose requirements for microhabitat are very specific.

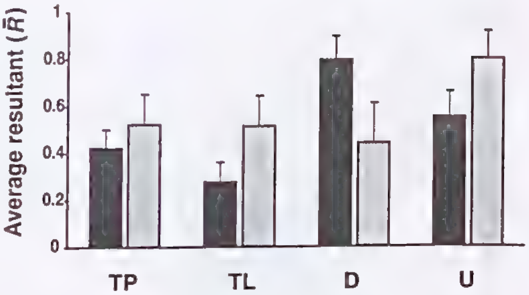

Fig 3. Directionality of movements by *Terebralia palustris* during the transplantation experiment shown as Rayleigh's $\overline{R}$ (+ SE). For Site II there are three replicate groups of snails per treatment. Only two replicates per treatment were available for Site I. The number of snails per group varies from five to 15 (see Table 3). (abbreviations as for Fig. 1).

The inclusion of the control treatments allowed an unambiguous interpretation of the results. For example, it was possible to discern that translocation affected the proportion of animals dispersing, but could not alone account for response of the animals to the main treatment. The fact that translocation had a detectable effect on behaviour emphasises the importance of this control (Chapman and Underwood 1992). The result suggests that *Terebralia* can either recognise the fact that it has been moved to a new environment or responds to the process of transit itself by increasing rates of dispersal. It was also shown that picking up the snails to paint them made little difference to their behaviour relative to animals left *in situ*. This is consistent with Chapman's (1986) findings for *Littorina unifasciata* and suggests that if necessary, the disturbance treatment might be omitted from future experiments on this species. It is, however, of value to incorporate all controls wherever possible as responses to disturbance may vary under different conditions and may thus confound investigations under some circumstances.

These results do not entirely falsify the alternative models raised in the Introduction. It cannot be concluded that the behaviour of adult snails is the sole mechanism by which the pattern of distribution arises and is maintained. Differential recruitment and/or mortality could also play a part, but their roles remain to be investigated. An assessment of the recruitment model could be made by an appropriately designed programme of monitoring the arrival of settlers and recruits to the different microhabitats. In practice, this would be a difficult under-

Table 4. Chi-square goodness of fit analysis. The distribution of experimental *T. palustris* with respect to (a) Open mud and (b) Mangrove canopy. All treatments combined. Expected values from data presented in Crowe (1997).

Microhabitat	Observed	Expected	χ^2	Probability
On open mud	46	130.18		
Not on open mud	290	205.82	136.77	< 0.001
Under canopy	290	122.10		
Not under canopy	46	213.90	362.67	< 0.001

taking because little is known about the timing of breeding in this species (Houbrick 1991) and juveniles settling from the plankton would be very small and hard to detect on the mud. Differential mortality of settlers or young recruits would be hard to test for the same reason, but adults could be tethered on open mud and under canopy to give an indication of the rates and possible causes of mortality in the two microhabitats. The support for the behaviour model does, however, raise questions about which differences between the two microhabitats provoke the response.

In exploring that question, care must be taken in interpreting the above results. To conclude that the snails 'prefer' to rest under the trees would be to over-reach the scope of the experiment. There remain several alternative explanations for the observed tendency of the snails to move away from open mud and aggregate under trees. It may be that the snails do indeed have a positive attraction to some feature of the microhabitat under trees. On the other hand, they may be ambivalent to that environment and are actually reacting negatively to a feature of the open mud. This distinction is not trivial, either from the point of view of the animal or of the researcher. From the animal's perspective, a negative pressure to leave the mud is potentially far more significant to its survival than a perhaps marginal positive inducement to move under trees. A researcher must consider both possibilities when planning further work or risk a lengthy investigation of alternative factors that may induce snails to move towards the favoured habitat, when in fact none are important because the animals are responding to some negative feature of the non-favoured habitat. The fact that the majority of transplanted snails had moved back to positions under the canopy after just two days suggests that the pressure to move, whether positive or negative, was quite strong.

One potentially negative feature of the open mud is exposure to heat and stress due to desiccation. Lasiak and Dye (1986) found that temperature and rate of evaporative water loss were substantially greater on the open mudflat than in the shade of mangrove trees in forests near Townsville. *Telescopium telescopium* (closely related to *T. palustris*) suffered significant mortality after three days on the exposed mud. McGuinness (1992) reported correlations at several sites between canopy cover and the abundance of another member of the superfamily Cerithioidea, *Cerithidea anticipata*. McGuinness (1994) provided evidence that snails at the centre and edge of canopy gaps experienced physical stress. More recently, McGuinness (pers. comm.) has shown that snails transplanted to the centre of canopy gaps remain if placed under shades (with appropriate controls). Thus animals may avoid bare mud to reduce physical stress.

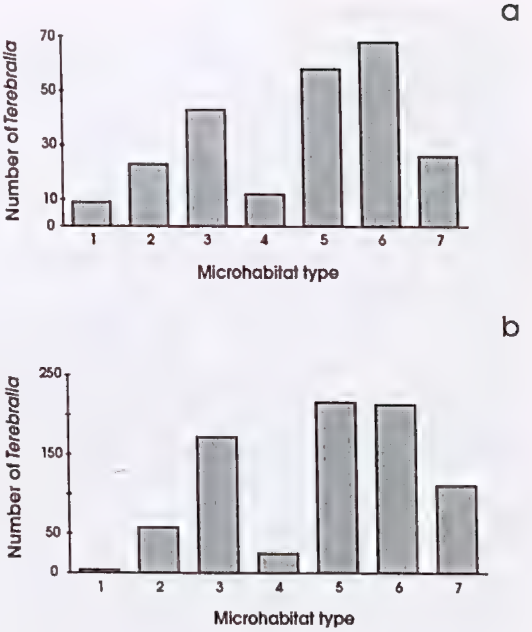

Fig. 4. Microhabitats occupied by experimental *Terebralia palustris* after two days. **(a)** Transplanted snails, Sites I & II combined (86 animals); **(b)** Pooled control treatments, Sites I & II combined (250 animals). 1 = open mud, 2 = within 1cm of fallen leaf, 3 = in contact with pneumatophore, 4 = in water >0.5 cm deep, 5 = under canopy of mangrove tree, 6 = shaded, 7 = within 5 cm of trunk of *Avicennia* or prop-root of *Rhizophora*. Note: the categories are not exclusive - each individual was scored yes/no for each of them.

Characteristics of the substratum may also change in relation to the distribution of trees. Marine molluscs are known to be sensitive to salinity (Fenchel 1975). J. R. Hanley (pers. comm.) found that salinity of the sediment was greater on open mud than under trees in the mangroves of Darwin Harbour. It is possible that the snails respond negatively to the increased salinity of the sediment. The size of the particles has also been shown to influence the distribution of marine molluscs (Barnes and Greenwood 1978). Wells (1980) found greater numbers of *T. palustris* on fine muds than in areas of coarser, sandy sediments in the Bay of Rest, W. A. It is not known whether this pattern is repeated in Darwin Harbour.

The fact that transplanted animals dispersed over greater distances could either indicate a response to positive or negative features of the physical environment, or it could be the result of an extensive foraging excursion involving an active search for a patch of food (see Chapman and Underwood 1992 and references therein). Potamidids are generally considered to feed on microflora in sediments (MacNae and Kalk 1962). Plaziat (1977, 1984) and Nishihira (1983) have also documented the direct consumption of fallen mangrove leaves by adult *Terebralia palustris*. Both of these sources of food may be present in greater abundance under trees than on open mud and may therefore attract the snails to that microhabitat. It would be necessary to examine the dietary preferences of the species in addition to patterns of distribution of its food in the different microhabitats as a first step in examining this question.

In the first of these papers, Crowe (1997) found significant correlations between abundance of *T. palustris*, percentage cover canopy and percentage cover leaf litter. In the light of this experiment, it is now possible to attribute the association with canopy, at least in part, to the behaviour of *T. palustris*. Leaf litter was not always correlated with canopy, suggesting that canopy and leaf litter may sometimes exert independent influences on *T. palustris*. In describing the microhabitat occupied by individuals at the end of this experiment, a distinction was made between 'featureless' open mud, and areas outside the canopy but nevertheless shaded or close to leaves or pneumatophores. Review of the literature suggests that these features may provide some of the cues causing snails to aggregate under canopy. *Terebralia palustris* may not respond to canopy *per se*, but to one, some or all of these associated features of microhabitat. The significant differences among plots in terms of distances moved indicate that the cues to which snails were responding were distributed at variable distances from the different plots.

To determine which factors elicit behavioural responses it is necessary to manipulate specific aspects of microhabitat. A series of factorial experiments is needed, in which combinations of food, shade, plant structures and sediment are manipulated. The behaviour of groups of individuals placed in the different treatments would have to be measured and compared to appropriate controls in order to establish which factors elicit positive or negative responses.

This experiment has (a) contributed to the interpretation of patterns of correlation between *T. palustris* and features of its environment and (b) provided a framework for continued research. It has therefore increased the prospect of elucidating the mechanisms and processes influencing the patchy distribution of an important component of the fauna in mangrove forests throughout the Indo-west Pacific.

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ARCHAEOLOGICAL EVIDENCE FOR ENVIRONMENTAL CHANGE IN DARWIN HARBOUR.

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ABSTRACT

Chronological change in the coastal environment of Darwin Harbour, Northern Territory, is documented by archaeological sites. Molluscs gathered by prehistoric people for food between 1,400 and about 900 years ago reveal that humans were foraging along largely open beaches. The dense and continuous mangrove forests found in the harbour today have formed in the last 1,000 years.

KEYWORDS: Archaeology, prehistory, middens, shell mound, Darwin Harbour, palaeoenvironments.

INTRODUCTION

Archaeological sites may be considered as convenient information traps, preserving evidence of environmental change. As part of their exploitation of the landscape, prehistoric humans procured food resources from the local area in which they lived. These hunter-gatherers carried materials to a locality where food debris was discarded and became protected in the archaeological deposit. In this way a selection of organic materials from past time periods has been preserved. While archaeologists typically concentrate on human economic activities represented by the food debris, archaeological material also reflects the kind of environment in which humans were foraging. Shell middens in particular have been used as indicators of environmental change in coastal landscapes. For example, in the Alligator Rivers region of the Northern Territory, Schrire (1982) and Allen and Barton (n.d.) have related change in shell midden composition to changes in the form or proximity of mangrove forests. Further to the west, along the Kimberley coast, Wells and Slack-Smith (1981: 273) used similar logic to infer chronological change:

> A number of Aboriginal kitchen middens are located on the hills adjacent to the Warrender mangroves. The middens are largely composed of marine molluscan shells and may reach a diameter of 5 m with a height of 1 m. The shells are mainly from the most abundant species of large molluscs in the mangal. An exception to this is the high percentage of valves of *Anadara granosa* (Linnaeus, 1758). This species was not encountered in the quantitative mangrove survey but a few live individuals were collected on the surface of the mudflat seaward of the swamp. The large number of *Anadara* shells in the middens suggests that once the species was more abundant in the area than it is now. The middens have not been dated so we have no idea of the period in which the population declined.

Similar shell mounds are found around Darwin Harbour, where they are typically located on raised rocky knolls and slopes, less than 20 m above sea level, overlooking the mangroves. These shell middens are also dominated by *Anadara* not found in the mangrove-lined coast, and are indicative of different coastal landscapes. Fortunately, archaeological investigations in the Darwin region are beginning to reveal the antiquity of these shell middens, and by implication those past coastal environments. This paper describes the environmental implications of archaeological excavations at one shell midden near Darwin.

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BAYVIEW HAVEN 3

Bayview Haven 3 is a mound of shell situated south of Tiger Brennan Drive on a promontory of land jutting out into Francis Bay (Australian Map Grid 701 305E, 862 4175N) in Darwin harbour. At this point there is a broad fringe of mangroves around the edge of the bay, and land rises steeply to more than 20 m above sea level.

The shell midden is located on the top of a ridge, 30 m from a steep hill slope. Vegetation is predominantly grass. There has been extensive disturbance in this area and a road passes very close to the site. Recent activities in this area have adversely affected this shell midden, but the bulk of the deposit remains intact. The shell midden is approximately 10-12 m in diameter and has a 50 cm deposit of shell material. In 1993, archaeological excavation of the site took place. Shell-rich sediments recovered from the deposit were typical of archaeological middens, containing bones of fish and macropods together with abundant large shells generally well preserved in a highly alkaline matrix. A small number of stone artefacts were also found. All material from this trench was sieved through paired 6 mm and 3 mm meshes, and the 6 mm sieve residues provide a quantitative measure of the kinds of molluscan fauna procured in the past.

Faunal composition. Relative abundance of the various invertebrate taxa represented in the midden was calculated using standard zooarchaeological measures (as described in Grayson 1984). For each taxon the weight and number of identified shell fragments (called NISP) were recorded. An estimate of the minimum number of individual (called MNI) molluscs necessary to account for the fragments of each taxon was based on the number of distinctive elements (hinges for bivalves and apertures for gastropods) in each excavation spit. These measurements were completed for spit 9, square F0, a unit of the deposit 1 m^2 in area and 6 cm thick. This excavation unit is typical of the midden and can be used to typify faunal composition.

A total of 7007.9 g of marine shell was retained in the 6 mm sieve from this excavation unit. Of this material only 101.4 g (1.4%) was not identified to genera. These unidentified fragments were small, often only 3-5 mm in maximum dimension, heavily weathered and without diagnostic features. The remaining 6906.5 g of marine shell was identified, counted and weighed. Faunal composition is summarised in Table 1. This assemblage is entirely consistent with economic activities of hunter-gatherers selecting for large, edible shell fish. This shell midden consisted of shells of animals from several gastropod genera (*Telescopium, Terebralia, Nerita, Chicoreus, Cassidula,* and *Pugilina*) and several bivalve genera (*Anadara, Marcia, Crassostrea, Geloina, and Placamen*). As quantified by weight, NISP or MNI calculations, *Anadara* is the numerically dominant taxon (Table 1). At least three-quarters of the midden mound consisted of fragments of shells from *Anadara*. Archaeological investigations aimed to determine the time period in which these *Anadara*-dominated piles of shell accumulated.

Radiocarbon chronology. Antiquity of the site was evaluated by submitting four samples of *Anadara* shells to radiocarbon analysis. C13 adjusted assays were calibrated using the University of Washington's CALIB 3.03 program, implemented with the marine bidecadal data set and the standard Delta R value of -5±35. Resulting age estimates are provided in Table 2.

These data, particularly Beta-72152 and Beta-72153, reveal that the latest shells deposited on

Table 1. Quantitative description of molluscan faunal debris in spit 9 of square F0 at Bayview Haven 3.

Genus	Weight of fragments (in grams)	Number of Fragments (NISP)	$\mathrm{MNI}_{\mathrm{Spit}}$	% by weight	% by NISP	% by MNI	Rank (by MNI)
Anadara	5703.8	5092	348	82.6	84.3	74.5	1
Nerita	51.4	107	33	0.7	1.8	7.1	2
Terebralia	354.8	202	24	5.1	3.3	5.1	3
Telescopium	430.9	291	15	6.2	4.8	3.2	4
Cassidula	6.6	19	13	0.1	0.3	2.8	5
Chicoreus	153.0	196	11	2.2	3.2	2.4	6
Pugilina	151.0	68	10	2.2	1.1	2.1	7
Marcia	30.4	30	6	0.4	0.5	1.3	8
Crassostrea	15.6	25	4	0.2	0.4	0.9	9
Geloina	7.7	11	1	0.1	0.2	0.2	10
Placamen	1.3	1	1	0.1	<0.1	0.2	11

the mound came from molluscs that died approximately 700-1050 years ago, and probably 850-950 years before present (bp). At some point within that period, deposition of food debris on the midden ceased, and the mound was abandoned.

In deriving these chronological estimates of site abandonment the standard Australian -450±35 years marine reservoir correction factor was used. It is worth noting that there is some evidence in favour of a smaller marine correction factor in the greater Darwin region (Woodroffe *et al.* 1988: 98; Scott Mitchell pers. comm.). If a smaller correction factor were appropriate, then the corrected and calibrated dates in Table 2 would slightly under-estimate the antiquity of the final occupation of the site. Nevertheless, any future revision of the marine correction will have minimal effect on the estimated age of occupation at the mound, and it can be concluded that the site was in use until approximately 700-1000 years ago.

The earliest age estimate, from the base of the shell deposit in square G8, indicates that formation of the deposit had begun at least 1250-1550 years ago. Since dated samples came from only the eastern part of the site, it is possible that shell in square G8 might have accumulated after other portions of the midden were already in place. Beta-72155 should therefore be considered a minimum age for the mound, but probably provides a useful indication of the date at which shell started to be deposited.

Using these corrected and calibrated radiocarbon dates, it is clear that humans occupied the site for at least 300 years, and possibly for as much as 850 years. A best estimate for the duration of site occupation is about 500 years, with occupation beginning about 1400 years ago and ending 900 years ago. Throughout the history of occupation the faunal assemblage remained remarkably similar, being dominated by *Anadara* in all levels. The dominance and persistence of this bivalve in the mound has implications for palaeo-environmental reconstructions of the harbour shorelines during the late Holocene.

Palaeo-environmental implications. Using MNI_{spit} as a measure of the number of animals captured by the people who discarded debris at Bayview Haven 3, it is clear that at least several hundred thousand individuals of *Anadara* are represented at the site, whereas only a few thousand molluscs typical of the current mangrove communities are present. This pattern cannot easily be reconciled with selective gathering of *Anadara* from within the existing mangroves or along the mangrove margins. The archaeological pattern is more likely to reflect the general availability of the mollusc taxa within the local prehistoric landscape.

Anadara, which forms the bulk of the mound, thrives on the silty-sandy substrates of open beaches (Broom 1985). Shorelines of this type are rare in the north-eastern portion of the Darwin Harbour embayment, and today do not occur near Bayview Haven 3, where dense stands of mangroves currently extend several hundred metres from the base of the colluvial hill slope into the harbour.

Cessation of mound building at Bayview Haven 3 is therefore likely to have been associated with environmental change in shoreline characteristics. It is hypothesised that during the period over which the site formed, roughly 900-1400 years ago, the local shoreline consisted of largely open beaches, perhaps with scattered stands of mangrove but without the dense and continuous mangrove forests found today. The presence of molluscs occupying sandy substrates, such as *Marcia* (see Lamprell and Whitehead 1992), within the midden, support such a proposition.

If this were the only evidence available it would be consistent with small scale chronological variations in the density of mangroves in the extreme north-east of the harbour. However, other archaeological evidence suggests that open

Table 2. Radiocarbon dates from Bayview Haven.

Code	Sample	Sample (g)	C^{13} adjusted date	Calibrated date (bp)	One sigma range (Cal bp)	Two sigma range (Cal bp)
Beta-72152	F8/5s	44.9	1310 ± 60	873	765 - 921	693 - 974
Beta-72153	F8/8s	30.5	1370 ± 50	916	871 - 957	772 - 1034
Beta-72154	G8/4s	33.5	1520 ± 70	1058	966 - 1155	911 - 1241
Beta-72155	G8/1s	37.1	1870 ± 60	1395	1321 - 1494	1274 - 1552

coastlines may have been widespread. Ten kilometres to the south of Bayview Haven 3, a series of similar *Anadara*-dominated midden mounds on the Middle Arm Peninsula have been dated by the author (further descriptions of these sites are being prepared). Samples of *Anadara* shells from the surface of four sites were radiocarbon dated and subjected to correction and calibration as described earlier for the Bayview Haven 3 samples. Resulting age estimates indicate that the upper levels of these *Anadara*-rich middens ceased accumulating about 700-1000 years ago (see Table 3).

Archaeological evidence therefore reveals that in two separate locations on the eastern side of Darwin Harbour, *Anadara*-rich midden deposits ceased to accumulate roughly 700-1000 years ago. I have advanced the argument that the composition of these middens largely reflects the relative availability of various molluscan taxa within the landscape. If that is the case, then the cessation of the *Anadara*-dominated middens probably signifies declining abundance of *Anadara* within the harbour and the expansion of mangrove communities at the expense of relatively open shorelines. The spatial extent of such environmental changes is ill-defined, but may well be widespread within Darwin Harbour. Consequently the palaeo-environmental implications of archaeological shell middens along the eastern margin of the harbour is that the dense, extensive mangrove communities found today may have an antiquity of not more than 700-1000 years.

CONCLUSIONS

Archaeological investigations near Darwin have palaeo-environmental implications and raise a number of questions concerning environmental change in Darwin Harbour. Issues addressed in this paper can be listed as follows:

1. On the eastern side of the harbour there are a number of mounded archaeological middens that are composed largely of *Anadara* shells. These middens ceased accumulation approximately 700-1000 years ago. At least one of these middens, Bayview Haven 3, began to accumulate about 1400 years ago.
2. Middens of this kind are thought to reflect the economy and diet of prehistoric people, and to indirectly reflect the availability of food species within the environment. In this instance, the shells of *Anadara* are so overwhelmingly abundant that it is suggested that that taxon must have been more abundant relative to other molluscs during the period in which the sites formed. By reference to the preferred habitats of the molluscs represented in the archaeological assemblage, it is hypothesised that the harbour shore consisted of open beaches with scattered stands of mangrove. Consequently, archaeological evidence suggests the dense, extensive mangrove communities found today may have an antiquity of only 700-1000 years.

This conclusion can be tested in a number of ways. Archaeological investigations throughout at least the eastern portions of the harbour should continue to document *Anadara*-rich middens dated to the second millennia before the present if open shores were widespread. Furthermore, there may be geomorphic or palynological evidence for a substantial increase in mangrove stands during the last thousand years. Such evidence has been successfully used in the Alligator Rivers region to define changes in estuarine/coastal conditions (see Woodroffe *et al* 1986), and has the capacity to test the proposal advanced here.

If the palaeo-environmental trends discussed here are corroborated by further research, it remains necessary to place those changes within a longer-term framework of landscape transformations. Archaeological evidence described in this paper cannot differentiate between two possibilities:

1. Extensive mangrove communities developed for the first time only in the last 700-1000 years.

Table 3. Radiocarbon dates from Middle Arm.

Code	Site	C^{13} adjusted date	Calibrated date (bp)	One sigma range (Cal bp)	Two sigma range (Cal bp)
Beta-55467	HR5	1420 ± 60	948	904 - 1029	819 - 1108
Beta-55464	HR14	1150 ± 50	678	646 - 735	610 - 801
Beta-55465	HR15	1500 ± 60	1042	956 - 1124	910 - 1197
Beta-55466	HR17	1380 ± 60	921	873 - 974	765 - 1059

2. Mangrove communities were widespread within the harbour prior to about 1400 years ago, but became spatially restricted for a period following environmental change (such as a series of severe cyclones). In this scenario it is possible that repeated cycles of mangrove destruction and re-colonisation have occurred and that this evidence identifies the most recent of these cycles.

Future research, by archaeologists and others, may determine which possibility best describes the late Holocene environmental history of Darwin Harbour.

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APPROACHES IN MANGROVE PLANTING: SOME OPTIONS FOR DARWIN MANGROVES.

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ABSTRACT

Mangrove forests throughout the world are being lost or damaged through direct utilisation, pollution or natural destruction. A review is presented of mangrove plant material used for revegetation projects, and the propagation techniques used. Two experiments were carried out using five Darwin Harbour mangrove species grown from stem cuttings and 10 species grown by air-layering. Cuttings established in a nursery may be the most economical propagation method.

KEYWORDS: Northern Territory, Australia, Darwin Harbour, mangroves, revegetation, propagules.

INTRODUCTION

The world's mangrove forests are estimated to cover at least 14 million hectares (Maltby 1991), representing 75% of the coastlines between latitudes 25° north and south (McGill 1959). Eighty species of plants belonging to about thirty genera in over twenty families are accepted as mangroves (Hutchings and Saenger 1987). The ecological and geological significance of mangroves is well recognised (eg. Davis 1940; Hutchings and Saenger 1987). Besides the ability of mangroves to stabilise sediments, they also protect shorelines from erosion and act as attenuators of storm-waves (Teas 1977). Mangroves play a major role in marine food-webs by providing feeding and breeding habitats for a great variety of organisms including bacteria, fungi, micro- and macro-algae, ferns, epiphytic angiosperms, invertebrates, reptiles, fishes, birds and mammals.

The effect of human activity is a major factor threatening wetlands in general and mangroves in particular. The nature of this effect is greatly dependent on the socio-economic status of the countries in which these mangroves occur. In developed nations, wetlands are often altered or destroyed for purposes of agricultural, industrial and urban development. Large areas of mangroves have been lost through dredge and fill operations, construction of ports and harbours, power-generation facilities, and land reclamation for urban expansion. For example, in the United States alone, 54% of wetlands have been lost. Tampa Bay and Biscayne Bay, Florida, have lost 44% and 82% of their mangroves respectively (Lewis 1982), whereas in Australia, 33% of the mangroves in Botany Bay have been lost (State Pollution Control Commission 1980; Lewis 1982).

In the Third World, direct utilisation is the major cause of mangrove loss (see current uses of mangrove species described in Hamilton and Snedaker 1984). The fact that most of the world's mangrove areas occur in some of the poorest nations increases the demand on this type of resource (Maltby 1991). High population demand for timber as a building material and even firewood has resulted in the over-harvesting of these forests. Conversion of wetlands to an alternative land-use has been a more recent phenomenon. Areas of natural mangroves are being converted to rice paddies and aquaculture in many of these countries (Cruz 1980).

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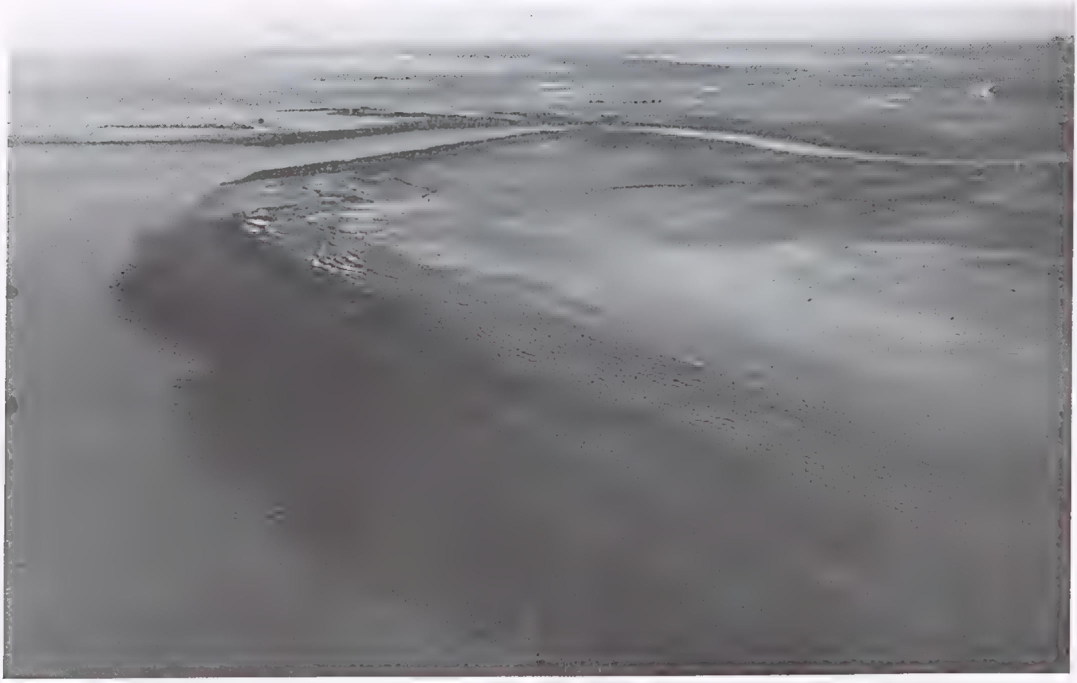

Fig 1. Aerial photograph for the mangrove stands at the mouth of Wildman and Alligator Rivers showing a complete missing zone of mangroves as a result of Cyclone Tracy in 1974. Photographed by Peter Saenger, 1980.

Recent reviews on mangrove status in developing nations show the actual size of the problem. Only 25% of the original area of mangroves remain in Puerto Rico; between 1967 and 1975 an annual loss of 24,000 hectares was reported from the Philippines; Thailand has lost up to 20% of its mangroves in the last decade (MacIntosh 1983); nearly 75% of mangroves in the Indus delta in Pakistan are either severely degraded or totally denuded (Qureshi 1990), and some species have been lost completely from the delta (Kogo *et al.* 1986); Ross (1975) has described the extensive aerial defoliation during the Vietnam war by the military use of herbicides.

Oil spills comprise another factor affecting mangrove areas. In 1985, it was estimated that between 1.7 and 8.8 million metric tons of petroleum per annum discharged into marine environments (National Academy of Sciences 1985). Knowledge of the effect of oil on mangrove ecosystems is extremely limited (Burns *et al.* 1993). However, many authors reported that leaf defoliation, and/or deformation, stunted seedling growth, damage to aerial roots, and high mortality in both seedlings and mature trees are very common in mangrove areas affected by oil pollution (eg. Getter *et al.* 1981; Wardrop *et al.* 1987; Dutrieux *et al.* 1990). Klekowski *et al.* (1994) have also reported that mangroves (eg. *Rhizophora mangle*) of oil-polluted habitats may experience increased mutation rate.

Recovery of mangrove vegetation from oil pollution is generally dependent on the size of the spill. Burns *et al.* (1993) demonstrated that mangrove ecosystems may need more than 20 years to recover from catastrophic oil spills. The common anoxic condition in many mangrove habitats causes long term persistence of the oil trapped in the sediments.

Natural destruction of mangroves by hurricanes, cyclones and lightning strikes is common in tropical areas. Craighead (1971) described the devastating effect of hurricanes in 1953, 1960, and 1965 on the mangroves in southern Florida. In northern Australia, cyclones typically occur during the wet season, especially on the north-east and south-east coasts of the Northern Territory (Wightman 1989). Strong winds and storm surges associated with cyclonic depressions often result in massive destruction of mangrove stands. Stocker (1976) reported the extensive damage caused by Cyclone Tracy in 1974 to mangrove vegetation in the Darwin area. Ten years later, Bardsley (1985) described a similar effect of Cyclone Kathy in 1984 on the mangrove vegetation of the Alligator Rivers region. (Fig. 1).

Regeneration by secondary succession can often repopulate damaged mangrove forests (Bacon 1970; Hamilton and Snedaker 1984). In some cases, however, mangroves do not readily become re-established on bare soils. Macnae (1968) reported that mangrove forests which have been clear-cut may fail to re-establish, but instead develop into non-vegetated saline areas. Active restoration efforts can speed up the natural recovery process (Teas *et al.* 1975).

Only in recent years have a few countries developed national or regional policies for wetland protection and management. These policies have been supported to a variable extent by educational and research programs (Maltby 1991).

Mangrove communities in Darwin Harbour are some of the most floristically diverse in the Northern Territory (Wightman 1989). With the rapid increase in the recreational, residential and industrial development around the Harbour, further pressure would be expected on these communities. The present review provides some background on different approaches of mangrove propagation which may be useful for rehabilitation or revegetation projects.

WHY PLANT MANGROVES ?

Various attempts at mangrove planting have been chronologically reviewed by Lewis (1982). Many of these attempts have been undertaken for a variety of reasons. Controlling shoreline erosion by planting mangroves started at the beginning of this century. Mangroves were introduced into Hawaii in 1905 in order to protect the coastline on the island of Molokai (MacCaughey 1917). The mangrove *R. apiculata* has been planted in Sri Lanka (Ceylon) to induce silt deposition and to stabilise the soil (Macnae 1968). For the same purpose, a large-scale afforestation project was initiated in 1966 in Bangladesh. About 0.12 million hectares of the coastal belt had been brought under plantation by 1990 (Siddiqi *et al.* 1993).

Mangroves have also been planted for revegetating damaged areas. A large number of mangrove plantation trials were carried out in Florida as early as 1917 (see review by Teas 1977). In Australia, more than 50,000 mangrove seedlings were transplanted from areas cleared for the construction of Brisbane airport and re-established along either side of a man-made creek for approximately 7 km (Saenger 1984). Similarly, Pakistan initiated a mangrove afforestation and rehabilitation project in 1986 (Qureshi 1990). Walsh (1974) reported an early attempt at planting mangroves for silviculture purposes in coastal areas of the Andaman Islands, India, in 1898. In Java, mangroves have been planted to stabilise the banks of fish ponds and canals (Macnae 1968).

SELECTION OF PLANT MATERIAL

Plant size and source are the most important factors in successful establishment of planted mangroves. Other important elements such as shoreline energy, root-parasite prevalence, depth of planting, substrate type, water salinity and vandalism were identified by Teas (1977). This paper discusses the types of plant material that may be utilised in rehabilitation processes in the Darwin region.

In most plantation trials described in the previous section, one or more of the following approaches has been involved: (1) direct use of seeds or propagules; (2) transplantation of nursery grown seedlings; (3) transplantation of naturally raised seedlings; (4) transplantation of older trees from natural mangrove stands; and (5) air-layered material. These sources of plant material are discussed in detail below.

Propagules. A propagule is any part of the plant capable of growing into a new individual and for mangroves includes seeds, fruit and viviparous seedlings (i.e. seed that germinates while the fruit is still attached to the parent tree). Late in the fruiting season large numbers of mature propagules can be collected, transferred and planted directly at selected sites. Propagules may either be scattered on the surface or gently pushed into the sediments to a depth between one and a few centimetres (Saenger 1984). Spacing distance is recommended to be 40-100 cm (Lewis 1982). However, as propagules are only generally available for two to three months of the year, transplantation needs to be scheduled according to their seasonal availability. Additionally, the high susceptibility of propagules to desiccation, dislodgment by waves and tides, predators and debris, make this material unsuitable for sites of high energy. The State Pollution Control Commission (1988) recommended propagules for more protected sites or areas that already have some mangrove stands. Hamilton and Snedaker (1984) and Saenger (1984) suggest that planting of propagules should be carried out during cool weather and on flood-free days.

Teas (1977) reported an interesting experiment on planting mangrove propagules by air in southern Florida. For soft inaccessible areas, a technique was developed by which propagules of the red mangrove, *R. mangle*, could be planted directly from a helicopter flying at altitudes of 30 m and speed of 160 km/h. Unrooted propagules were enclosed in sand-filled paper bags from which the tips of the propagules projected (see Teas 1977). Successful establishment of seedlings was reported after four to six months. The advantage of such a technique is the ease of reaching sites that are inaccessible by other means. However, the high cost of this method reduced the feasibility of it being used in smaller projects.

Naturally grown seedlings. In this technique, young seedlings are removed from the natural mangrove forest and transplanted to sites under rehabilitation. The most common seedling height is <0.5 m. Young seedlings are best removed by using a 10 cm PVC pipe as a corer, pushed 20-25 cm into the substrate around the seedling (State Pollution Control Commission 1988). Transplants should be kept moist and protected from direct heat and wind during collection and transport.

There are several advantages of this source of young seedlings: (a) unlike propagules, they can be collected at any time of the year; and (b) transplantation of these seedlings may provide a better chance of establishment in sites where they can grow to mature trees rather than remaining in the understorey of the mature forest, where they have to compete for light and space (Macnae 1968).

Once again success and growth rates of these seedlings are highly variable, depending on the characteristics of the site; but they are more reliable than propagules.

Nursery raised seedlings. Raising mangroves in nurseries is an approach to minimise problems associated with transplantation of young

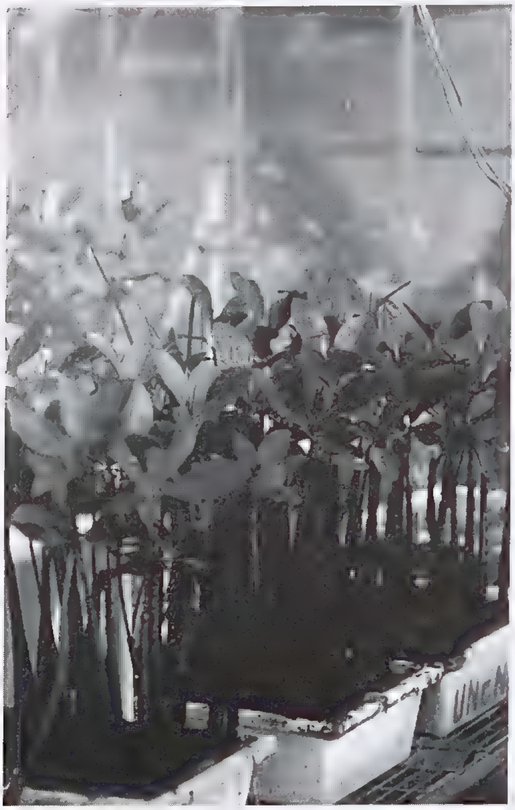

Fig 2. One year old *Rhizophora stylosa* grown from propagules under nursery conditions in saturated substrate.

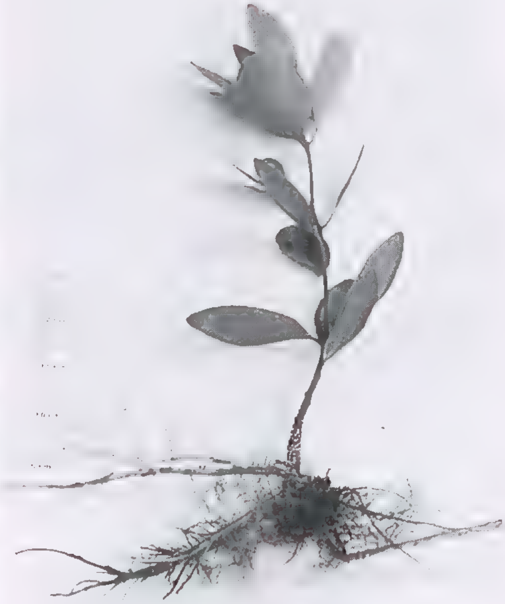

Fig 3. A one year old *Aegiceras corniculatum* grown from propagules in saturated substrate under nursery conditions.

seedlings from natural stands. The technique itself is relatively simple; propagules of different species can be collected late in the fruiting season and then grown on freely drained sandy substrate. Soil has to be kept damp, preferably with 25% sea water (to reduce fungal infection). Relatively high temperatures and humidity is essential for mangrove growth. Indirect sunlight of about 400 µmol m^{-2} s^{-1} Photosynthetic Active Radiance (PAR) is more effective in producing a larger leaf area than direct sun light (personal observation). Based on the fact that mangroves appear to respond to fertilisers in early stages (Teas 1977), it is recommended that once roots have started to develop and the first pair of leaves expanded, the pots are saturated with 25% sea water containing 2% liquid fertiliser (e.g. Aquasol; Hortico, Sydney). This allows greater root growth and healthier shoots to be obtained (Figs 2-3). Furthermore, it reduces the risk of the seedling becoming desiccated by infrequent watering. Nutrient solutions should be changed at least once a month.

The benefit of raising seedlings in nurseries is that it provides a year-round supply, which is of particular importance in large scale projects. It also provides a potential means of obtaining more rapid growth and substrate stabilisation than could be expected from planting propagules.

Young trees from natural mangrove stands. Few reports have described trials of transplantation of young mangrove trees from natural forests. The extensive root system of young mangrove trees offers the promise of greater and faster success of establishment than could be expected from seedlings. Therefore, these individuals would have a better resistance to wave erosion and debris and can be transplanted into sites of higher energy where propagules or seedlings are unlikely to survive. Areas under construction or reclamation can always be used to provide stock plants.

Most of the successful trials have used trees of heights ranging between 0.5 and 1.5 m (e.g. Gill 1971; Pulver 1976; Evans 1977; Goforth and Thomas 1980). Pulver (1976) indicated that because it would take four to six years for seedlings raised in a nursery to reach that height, such an approach can be quite practical if done under suitable conditions. Much taller trees do not seem to have any advantages. Failures in transplanting *Avicennia germinans* and *Lumnitzera racemosa* trees up to 6 m tall have been reported by Teas (1977).

Although young trees are available throughout the year, the fact that they must be supplied at the expense of other natural stands, which may cause severe disturbance to the rest of the plantation, indicates the importance of trying other less destructive, faster, and more efficient approaches in obtaining stock plants for revegetation work.

In general, each of the above described techniques has its own drawbacks. Many reports indicate high seedling loss even in protected sites. It also takes between two to four years for the young surviving propagules to establish themselves. Extensive disturbance caused by transplantation processes from stocking areas of natural forest may damage the remaining vegetation. The costs associated with all these techniques are high. For these reasons, research on the possibility of propagating mangroves vegetatively (for example by air-layering and/or cuttings) is urgent. This approach may reduce cost and time, and bypass the problems associated with using other plant sources.

Air-layered materials. Carlton and Moffler (1978) successfully propagated three mangrove species by air-layering. This is a technique in which short sections of bark and phloem of mature lateral branches are removed until the cambium becomes exposed, and the injured area of the stem is then wrapped with *Sphagnum* moss in aluminium foil to retain moisture. After roots have developed, the stem is cut below the layering area and the new plant is then ready to use.

Unlike raising young seedlings, air-layering method can reduce the risk of root damage by insects and crustacean pests especially in the early stages of establishment. However, the technique has to be done on mature trees and presumably in the field, which is not only inconvenient but also still subject to many other biotic and abiotic variables that cannot be controlled (e.g. the risk of fungal and bacterial infection, fluctuation in temperature and rain fall, and tide height).

In addition, the technique apparently did not reduce the cost. Carlton and Moffler (1978) calculated that it cost $150 to produce 1000 air-layers. The success rates ranged between 39% for *Rhizophora mangle* to 6% for *Avicennia germinans* which means that the actual costs will be between $385 and $2500 per 1000 successful air-layers respectively. That may explain the lack of any report for mangrove revegetation in which air-layering was used to propagate the stock plants.

Further investigations are certainly required to increase the success rate with the above species, and assessing additional species. Improving technique effectiveness by applying rooting hormones or using different types of wraps should be considered. Seasonal effects on producing quicker and stronger rooting response through air-layering also require further research.

For screening the susceptibility of some other mangrove species to produce roots using air-layering, a small experiment with 10 different mangrove species was carried out in July, 1993, at Woods Inlet, Cox Peninsula, west of Darwin Harbour. These species included *Aegialitis annulata, Aegiceras corniculatum, Avicennia marina, Bruguiera parviflora, Ceriops decandra, Excoecaria ovalis, Rhizophora stylosa, Osbornia octodonta, Thespesia populneoides* and *Sonneratia alba.* The technique applied was similar to that described in Carlton and Moffler (1978), except that dark plastic sheets were used instead of aluminium foil. Also, 50% liquid rooting hormone (Rootex-L; Bass Lab.,Victoria) containing 40 ppm Indole Butyric acid (IBA) was used. A total of 30 air-layers (three per species) took two days to prepare. All air-layers were located above the highest tide mark.

After three months, only *Rhizophora stylosa* have shown swellings that indicated possible root initiation. None of the other nine species has shown any clear response. Failure of these species to respond to the treatment may be partially attributed to other environmental factors. For example, *Aegialitis annulata* was completely submerged a few times during the experiment.

OTHER POSSIBLE OPTIONS

There are a few parameters that determine the suitability of different stock plants for restorative work: (1) availability of the source during the year; (2) time required to reach suitable size before transplantation; (3) level of resistance to biotic and abiotic variables, which also relates to the growth characteristics (such as the shoot height and root biomass) of the source; and (4) the costs involved.

In the work reported here, two separate experiments were conducted to provide other possible approaches that minimise the time and costs required for raising more suitable mangrove stocks and bypassing some of the problems highlighted above.

Nursery establishment of transplanted seedlings. One hundred seedlings of *Avicennia marina* of less than 20-25 cm in height were dug out of a mature stand in the Richmond River Nature Reserve, NSW. The selected seedlings had an average of two pairs of leaves and the cotyledonary leaves were completely detached. On site, soil was carefully washed off the roots and the seedlings were transferred to a nursery and planted in acid-washed coarse sand and then immediately saturated with 25% sea water containing 2% liquid fertiliser (Aquasol; Hortico, Sydney). Water level was maintained at 2 cm above the soil surface. After one month, survival rate was more than 90%. Seedlings showed an exceptional root recovery and strong shoot growth. After 12 months, the average height of the seedling ranged between 50-70 cm (Fig. 4).

With this approach the advantages of both nursery raised seedlings and small seedlings transplantation (<50 cm) have been combined.

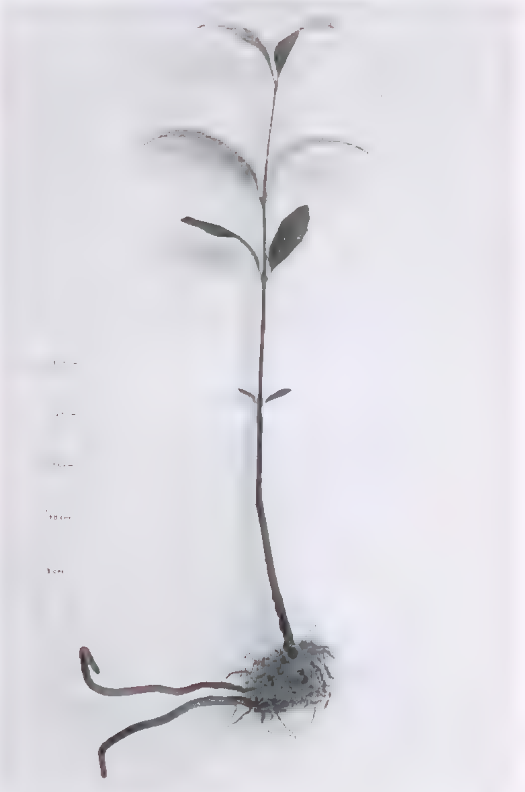

Fig 4. *Avicennia marina* seedling after 12 month nursery establishment, showing strong root and shoot growth.

Damage to the donor site has been avoided by using small seedlings. The technique also reduced the time required for the propagules to grow to the required height (50 to 70 cm). It would also be expected that seedlings of that height would have a high survival rate when transplanted into the field.

Mangroves grown from stem cuttings. Five mangrove species were selected: *Avicennia marina*, *Excoecaria agallocha*, *Rhizophora stylosa*, *Aegiceras corniculatum*, and the mangrove associate *Hibiscus tiliaceus*. From one tree of each species, twigs were subdivided into 10-15 cm cuttings. Starting from the terminal bud, the first, second and third segments represented the soft, semi hard, and hard wood respectively. Leaf area was reduced and cuttings were then dipped in 50% liquid rooting hormone (Rootex-L; Bass Lab., Vic). The cuttings were then planted in a mixture of coarse sand and peatmoss (2:1) and kept moist but well drained throughout the experiment. For each species, fifteen cuttings for each wood type were planted within 24 hours. This experiment was repeated three times - in July 1993, September 1993 and February 1994.

For all trials, only two of the five species were successful i.e. *Excoecaria agallocha* and the mangrove associate *Hibiscus tiliaceus* (Figs 5-6). However, for the first trial (July 1993), a 100% failure was recorded with all species regardless of wood type. In the second trial, *Excoecaria agallocha* gave a success rate of 90%, 60%, 30% with semi hard, soft, and hard wood respectively within three to four weeks. *Hibiscus tiliaceus* gave a 100% success rate with hard and semi hard wood while less than 50% with soft wood within two to three weeks. Trials in July 1993 and February 1994 were unsuccessful. In the last trial, *Hibiscus tiliaceus* gave similar results to the second one while *Excoecaria agallocha* showed a slower response (>2 months) and a lesser success rate with all wood types (about 30%).

In conclusion, a few factors are seen to be important for a successful mangrove cutting: (a) reduce transpiring leaf area as much as possible; (b) avoid wilting (by using a misting system or by covering pots and the cuttings with

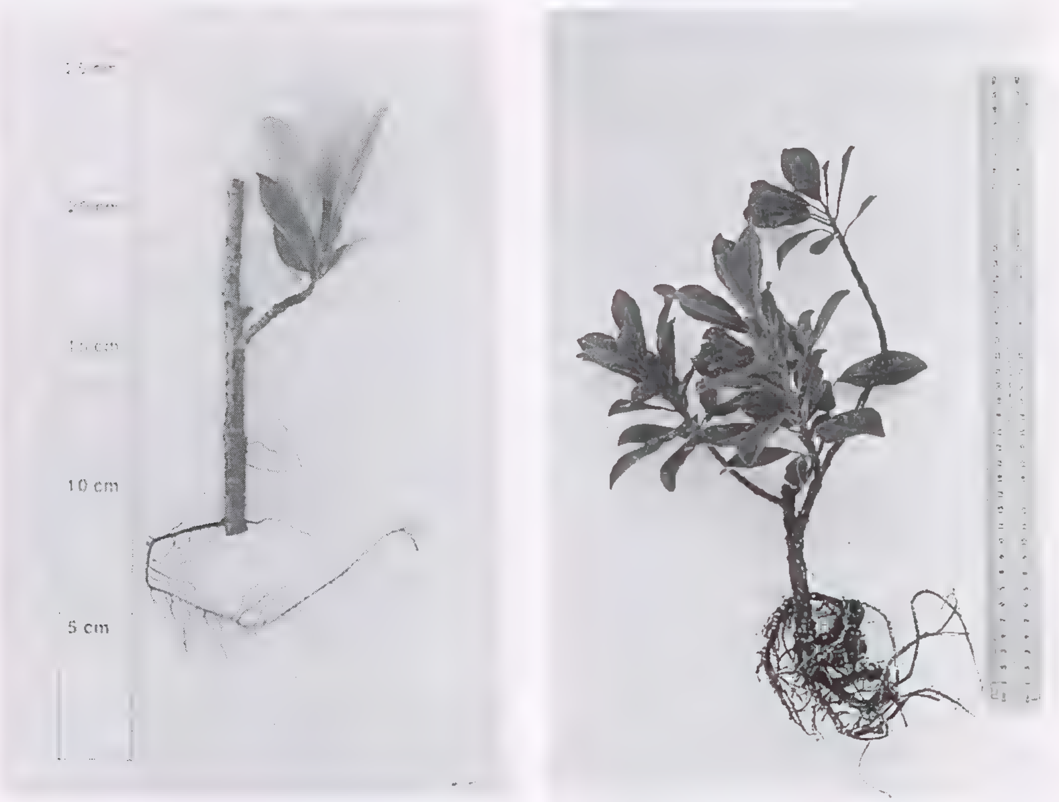

Fig. 5. Left, a two month old *Excoecaria agallocha* grown from stem cutting; **right**, a one year old *Excoecaria agallocha* grown from stem cuttings under nursery conditions in saturated substrate.

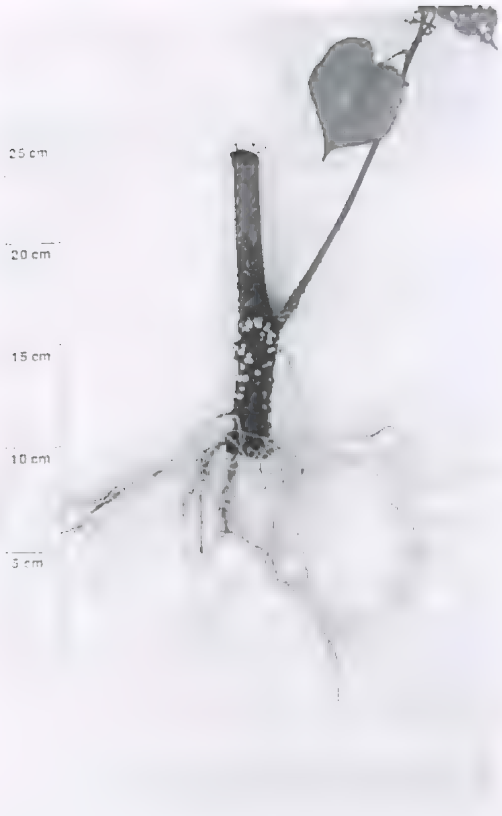

Fig 6. A two month old *Hibiscus tiliaceus* grown from stem cutting.

plastic bags); (c) apply rooting hormones to the cutting base, and keep the soil warm (i.e. about 27 °C); (d) cuttings should include at least two or more nodes; (e) cuttings should never be fertilised until roots have developed; and (f) flowers or flower buds should be removed entirely as it appears that cuttings taken at flowering time are generally less successful.

Excoeceria agallocha is one of many mangrove species that does not propagate by viviparous seedlings. Fruit of this species are have two or three seeds and 1 kg of green fruit contains about 2500 seeds. Siddiqi *et al.* (1993) described that it takes about three weeks for seeds to germinate with a 70% success rate and about 10 months to reach a height of 40-70 cm. Raising this species from cuttings will certainly save both time and effort.

Success in raising other species (e.g. *Rhizophora* and *Avicennia*) by air-layering (Carlton and Moffler 1978) and the induction of rooting in *R. apiculata* hypocotyls using Indole Acetic Acid (IAA) (Kathiresan *et al.* 1990), may indicate the possibility of raising these species from cuttings if it is done at the right time. Failure of the other three mangroves *(A. marina, R. stylosa,* and *A corniculatum)* to produce roots as well as the failure of *E. agallocha* and *H. tiliaceus* in one of these trials, may be related to the observation that in every case the mother tree was either flowering or fruiting.

There are many advantages to growing mangroves from cuttings. A fairly large number of trees can be propagated in a reasonably short time and for very little cost, time and effort. However, growth of cuttings is determined to a large extent by the growth rate of the species. Since mangroves are generally slow growers, the technique, unless starting with a large cutting, is still reasonably slow - though not as slow as growing from propagules. Further research is required to study the effects of cutting size and the optimal season and nursery conditions for propagating each species. The type of the rooting hormone and the dosage at which the hormone should be applied are interesting points for further investigation.

SUMMARY AND CONCLUSIONS

In the Darwin area, the frequent destruction to the mangrove stands by cyclonic activities or tropical storms and the rapid increase in the residential, industrial, and recreational development together may represent possible threats to this fragile habitat. In many countries that have similar developmental impact on mangrove areas, the appreciation of the environmental and economic value wetlands has enforced the necessity of developing proper management policies toward these forests. Many successful attempts for planting mangroves for the purposes of revegetating or rehabilitating damaged or cleared mangrove areas have been reported in many countries, including Australia. It appears, however, that success of these projects is dependent on many factors which related to the site condition, the climatic condition under which planting took place and the suitability of the plant material.

In this short review, different types of plant materials that can be utilised in revegetation or rehabilitation projects are critically compared. Two separate experiments were also conducted to provide other possible approaches that minimise the time and costs required for raising more suitable mangrove stocks and bypassing some of the problems associated with different techniques traditionally used in mangrove propagation.

Nursery establishment for transplanted young mangrove seedlings and/or using plant materials grown from stem cuttings are recommended as an alternative approach in preparing stocking plants. Establishing mangrove seedlings in a nursery before transplantation is suggested to have many advantages over direct transplantation or digging out older trees. Growing mangroves from cuttings, on the other hand, can save time and money if compared with raising plants from seeds (e.g. *Excoecaria agallocha*) or applying air-layering technique. Further investigations are required to study the possibilities of growing other mangrove species from stem cuttings as well as the starting with larger segments.

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COMPARISONS OF DIFFERENT QUADRAT SIZES FOR MEASURING THE DENSITIES OF CRABS AND MACROMOLLUSCS OF THE MANGROVE FOREST FLOOR.

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ABSTRACT

Two sizes of quadrats were compared to measure the densities of crabs, and four sizes of quadrats were compared to measure the densities of molluscs on a tidal mangrove forest floor in Darwin Harbour, northern Australia. No significant differences between quadrat sizes used for crabs were observed, however, densities of macromolluscs were significantly less in larger quadrats. Crab sampling can be satisfactorily undertaken with 1 m^2 quadrats; however, the appropriate size of quadrat for macromollusc could not be stated.

KEYWORDS: quadrat, mangrove, crabs, molluscs, Darwin.

INTRODUCTION

The size of sampling units and the number of replicates collected are the two aspects of sampling that most affect the precision of sampling estimates, with size being particularly important when organisms are aggregated (Andrew and Mapstone 1987). The aim of this study was to determine if there were significant differences between quadrat sizes when estimating crab and macromollusc densities on the mangrove forest floor in Darwin Harbour, Northern Territory. We also aimed to assess the precision and accuracy of the different quadrat sizes. We compared the density estimates from 0.25 m^2 quadrats to those of 1 m^2 quadrats for sampling the densities of crabs, and compared the density estimates between 0.25 m^2, 1 m^2, 25 m^2 and 625 m^2 quadrats for sampling the densities of macromolluscs on a tidal creek bank site in Darwin Harbour. While we acknowledged that the number and arrangement of quadrats are likely to affect the efficiency, precision and accuracy of a sampling program, we were concerned only with the comparison of different quadrat sizes.

Our personal observations in the mangrove forests of Darwin Harbour suggested that there was an approximately even distribution of crabs on the forest floor. This contrasted with our observations of an uneven distribution of molluscs. We hypothesised that there would be no significant difference in the crab density estimates provided from different quadrat sizes because of the crabs' even distribution, but there would be a significant difference in the mollusc density estimates from small to large quadrats. We expected that larger quadrats would record higher densities of molluscs and that smaller quadrats would miss the aggregations and therefore be less accurate than the large quadrats.

Andrew and Mapstone (1987) defined accuracy "as the closeness of a measurement to the true value" and precision as referring to "the

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In: Hanley, J.R., Caswell, G., Megirian, D. and Larson, H.K. (eds) *Proceedings of the Sixth International Marine Biological Workshop. The marine flora and fauna of Darwin Harbour, Northern Territory, Australia.* Museums and Art Galleries of the Northern Territory and the Australian Marine Sciences Association: Darwin, Australia, 1997: 461–466.

degree of concordance among a number of measurements or estimates for the same population". Because mangrove crabs can burrow or hide deeper in the burrows and may avoid surface sampling, our quadrats measured the relative densities of crabs and so we did not aim to assess the accuracy of these quadrats, only the precision. The macromolluscs however remain on the surface and our quadrats should have measured their absolute density, enabling us to assess the accuracy and precision of the quadrats.

Quadrats are commonly used for ecological sampling. Clements (1907, in Pringle 1984) defines a quadrat as "a square of varying size", although Krebs (1972) states that the word quadrat has been used in ecology for all shapes of areas. Pringle (1984), in reviewing marine littoral ecological literature, found the three most common sample unit configurations, the quadrat, circle and rectangle, had popularity ratings of 66.7%, 19.0% and 14.3% respectively, although the reasons for using them were not stated by their users.

Wells (1980) used 1x3 m (3 m^2) rectangles to measure distributions of mud-whelks in north-west Australian mangroves and Wells (1983, 1984, 1985) then employed a 0.75 m diameter (0.44 m^2) circle to measure distributions of molluscs, crustaceans and other marine invertebrates in the same area. Wells and Slack-Smith (1981) used 5x5 m (25 m^2) quadrats to measure zonation of molluscs in the Kimberley region of Western Australia and also derived density estimates for the species encountered. Hanley (1993a,b) employed 1x1 m (1 m^2) quadrats for mangrove crab studies in northern Australia for ecological assessment and monitoring projects.

Alternatives to, and variations on, sampling from quadrats have included the following. The use of video recording of quadrats in the intertidal community in Texas (Whorff and Griffing 1992), which enabled the digitising of selected frames of quadrats for further analysis. The technique appeared more suited to vegetation studies. DeBlois and Leggett (1993) found the use of a "sled-sampler" roughly equivalent in precision to that of quadrats in assessing the abundance of intertidal amphipods in Newfoundland. McClanahan and Muthiga (1992) compared time based searches with 5 m^2 quadrats for measuring densities of subtidal epibenthic gastropods in Florida. They found the search sampling effective in labour terms although data was produced in units of time rather than two-dimensional space. Moverly (1984) and Saenger (1988) used roofing tiles to estimate crab densities in Queensland mangroves, allowing crabs to gather under the tiles for about a month prior to sampling. Moverly (1984), however, noted that there was an active attractance to, and avoidance of, the tiles by different species and the method was only suitable for comparisons between relatively homogenous sites.

If quadrats are chosen as the sampling method it is important to choose the correct quadrat size (as well as the number and arrangement of quadrats). Pringle (1984) recommended sampling efficiency be determined prior to the initiation of an area sampling program, after concluding that a large number of small sampling units was more efficient than a smaller number of large sampling units. Lamontagne and Rasmussen (1993) however, found no significant difference between using 1 m^2 and 10 m^2 quadrats for estimating the density of crayfish in lakes in North America.

A potential benefit of measuring the densities of crabs is to provide an indicator of mangrove productivity. Saenger and Snedaker (1993) detailed how the regressions of mangrove biomass and litterfall show significant relationships with height of mangrove vegetation and latitude, and suggested that height and latitude are causally related to biomass while the relationship with litterfall reflects the specific growing conditions of the site. Current research (Smith, in progress) aims to detect a latitudinal trend in the standing stock of herbivorous mangrove crabs, which could be indicative of mangrove productivity. A possible advantage of such a determination would be as a supplement to the measurement of litterfall as a productivity-related feature indicator, and quantifying a link between primary and secondary production.

MATERIALS AND METHODS

The site selected for the sampling comparisons was located on a tidal creek bank at Sadgroves Creek, in the east of Darwin Harbour, 2.6 km north-east of Darwin General Post Office. The site was chosen for its accessibility from a main road and also to take the opportunity to sample prior to its possible destruction to allow urban development to proceed.

The study site was a dense mangrove forest dominated by *Rhizophora stylosa, Bruguiera* *parviflora* and *Avicennia marina* with the associated species of *Camptostemon schultzii* and *Ceriops tagal* occurring infrequently. The substrate consisted of fine, deep muds with thick beds of pneumatophores and other exposed roots. The mud was either moist, saturated, or covered by shallow pools over the site, resulting from the previous tidal inundation. Scattered organic debris consisted of leaves, twigs, branches and logs of the constituent trees. Scattered human debris was also present including cans, bottles, plastic, tyres and styrofoam. Bioturbation had resulted in numerous mounds up to 30 cm high occurring amongst the pneumatophores and other exposed roots. Crabholes into the mounds and mud were abundant, ranging in size up to 3 cm diameter.

Four sizes of quadrats (squares) were employed in this study, 0.25 m^2, 1 m^2, 25 m^2 and 625 m^2. Five 1 m^2 quadrats each divided into four 0.25 m^2 sub-quadrats, were compared with five undivided 1 m^2 quadrats for sampling the densities of crabs. These quadrats and sub-quadrats, five 25 m^2 quadrats and one 625 m^2 quadrat were compared for the sampling of the densities of molluscs.

Methods for selecting sampling sites and laying out quadrats followed closely that of Hanley (1993a,b). A large *Rhizophora stylosa* tree (one of many in the study site) was selected as a reference point becoming the centre of an imaginary circle 20 m in diameter. Numbers between 1 and 10 were drawn from a hat at random to allocate distances in metres from the reference point for each quadrat, in five different directions, north, south, east, west and north-west. The 0.25 m^2 sub-quadrats and the 1 m^2 quadrats were not permitted to overlap. At all times care was taken to avoid walking on any area which had not yet been sampled. The 625 m^2 quadrat was not selected using this system but was sited adjacent to and south of the imaginary circle.

Once the position of a quadrat was measured out from the reference point, four pieces of thin (1 cm diameter) orange, nylon rope, each 1 m long were laid out to encompass an area of 1 m^2. To establish the 20 0.25 m^2 quadrats, two more pieces of rope were laid across each of the appropriate 1 m^2 areas dividing each into four. To mark out the 25 m^2 and 625 m^2 quadrats, longer ropes were extended around appropriate corner trees to encompass the desired area.

All crabs that were observed in the 0.25 m^2 and 1 m^2 quadrats were collected and preserved in 70% alcohol, except for two large *Uca flammula* observed in sub-quadrat no. 2D that were not collected. Sorting and identification of collected crabs was undertaken in March, 1994. Molluscs were identified in the field and not collected. We conducted the counting of the molluscs together to minimise the chance of not overlooking any individuals.

Results of the crab counts were analysed by using Students t-test (Webb and Blackmore 1985), and results of the mollusc counts in the 1 m^2, 5 m^2, and 25 m^2 quadrats were analysed by a Kruskal-Wallis non-parametric ANOVA. Precision (*p*) was determined as standard error/mean, with the smallest value of *p* giving the most precise estimate (Andrew and Mapstone 1987).

RESULTS

Crabs. Results of the crab counts are presented in Table 1. *Perisesarma semperi* was the most abundant of the eight crab species recorded in the quadrats, accounting for 45 of the 100 crabs counted. *Perisesarma semperi* was also the most frequently occurring crab species in the quadrats, recorded in 13 of the 20 0.25 m^2 quadrats and in all of the 1 m^2 quadrats.

A total 55 crabs were recorded in the 20, 0.25 m^2 sub-quadrats, with an average density of 11.0 crabs.m^{-2} (range 0 to 32, sd 8.1, *p* 3.3). When considered as five groups of four 0.25 m^2 sub-quadrats, the average density was 11.0 crabs.m^{-2} (range 9-16, sd 3.4, *p* 0.7). The five, undivided 1 m^2 quadrats recorded a total 45 crabs with an average density of 9.0 crabs.m^{-2} (range 2-16, sd 5.5, *p* 1.4).

There was no difference between the variances of the 20 sub-quadrats and the five undivided 1 m^2 quadrats, f = 2.169 (d.f. 19,4, $20\%<p<50\%$), and also no difference between the variances of the subdivided and undivided 1 m^2 quadrats, f = 2.617 (d.f. 4,4, $20\%<p<50\%$). Also, there was no significant difference between means.

Molluscs. Results of the mollusc counts are presented in Table 2. Four species of macromolluscs were recorded, *Nerita balteata*, which occurred on lower parts of trees or on the mud, and three species of mud-whelks, *Terebralia palustris*, *T. sulcata* and *Telescopium telescopium*.

Table 1. Number of crabs recorded in 20 0.25m^2 quadrats (nos 1A to 5D), five 1 m^2 quadrats (nos 6-10), at Sadgroves Creek from 8-11 July, 1993.

Quadrat No.	*Perisesarma semperi*	*Perisesarma darwinensis*	*Uca flammula*	*Uca* sp.	*Clistcoelema merguiensis*	*Nanosesarma batavicum*	*Petrolisthes limicola*	Sesarmid sp. A	Total (Density crabs.m^{-2})
1A	-	-	-	-	1	-	-	-	1 (4)
1B	-	-	1	-	-	-	-	-	1 (4)
1C	4	-	1	-	-	-	-	-	5(20)
1D	2	-	-	-	-	-	-	-	2 (8)
2A	2	-	-	-	-	-	-	-	2 (8)
2B	1	-	1	-	1	-	-	-	3(12)
2C	4	-	1	2	-	-	1	-	8(32)
2D	-	1	2	-	-	-	-	-	3(12)
3A	2	-	-	-	1	-	-	-	3(12)
3B	-	-	-	-	2	-	-	-	2(8)
3C	1	-	-	-	2	-	-	-	3(12)
3D	1	-	-	-	-	-	-	-	1 (4)
4A	-	-	-	-	-	-	-	-	0 (0)
4B	-	-	-	-	-	1	-	-	1 (4)
4C	4	-	-	2	-	-	-	-	6(24)
4D	1	-	-	-	-	-	-	-	1 (4)
5A	2	-	-	1	-	-	-	-	3(12)
5B	1	-	-	-	-	-	-	-	1 (4)
5C	1	1	-	-	1	-	-	1	4(16)
5D	-	1	-	-	3	1	-	-	5(20)
6	3	6	-	-	2	-	-	-	11(11)
7	1	2	-	1	1	-	-	-	5 (5)
8	1	1	-	-	-	-	-	-	2 (2)
9	4	-	-	4	3	-	-	-	11(11)
10	10	4	-	-	2	-	-	-	16(16)
Total	45	16	6	10	19	2	1	1	100

Six molluscs were recorded in 20 0.25 m^2 quadrats in five sub-quadrats (15 of the sub-quadrats recorded no molluscs) with an average density of 1.2 molluscs.m^{-2} (range 0.0-8.0, sd 2.3, *p* 8.6). When considered as five subdivided quadrats the average density was 1.2 molluscs.m^{-2} (range 0.0-3.0, sd 0.4, *p* 2.2). The five, undivided 1 m^2 quadrats recorded 10 molluscs with an average density of 2.0 molluscs.m^{-2} (range 1.0-3.0, sd 0.7, *p* 1.1). The five, 25 m^2 quadrats recorded 55 molluscs with an average density of 0.4 molluscs.m^{-2} (range 0.3-0.9, sd 0.3, *p* 1.7). The 625 m^2 quadrat recorded 100 molluscs, a density of 0.2 molluscs.m^{-2}.

The very low numbers of molluscs counted in the subdivided and undivided 1 m^2 quadrats made statistical analysis difficult. However a Kruskal-Wallis non-parametric ANOVA between the 1 m^2, 5 m^2 and 25 m^2 quadrats indicated differences significant at p=0.02, indicating a trend that mollusc densities appeared to decline with increasing quadrat size.

DISCUSSION

The results for crabs in this study indicated that there was no significant difference between density estimates in the 0.25 m^2 quadrats to the 1 m^2 quadrats. Density estimates for crabs were most precise in the divided 1 m^2 quadrats (*p* 0.7) and least precise in the 0.25 m^2 quadrats (*p* 3.3). The results for the molluscs in this study indicated significant differences for density estimates in different quadrat sizes, with mollusc density appearing to decline with increasing quadrat size. Density estimates for molluscs were most precise in the undivided 1 m^2 quadrats (*p* 1.1) and least precise in the 0.25 m^2 quadrats (*p* 8.6).

Higher densities recorded in smaller quadrats may possibly be attributed to more time being spent per unit area in the smaller quadrats than the larger quadrats. This was not documented, but a time versus density factor could have been a significant contributor to the results. In the

Table 2. Numbers of molluscs recorded in 20 0.25 m² quadrats (no.s 1A to 5D), five 1 m² quadrats (no.s 6 to 10), five 25 m² quadrats (no.s 11 to 15) and a 625 m² quadrat (no. 16) at Sadgroves Creek on 11 July 1993.

Quadrat No.	*Terebralia palustris*	*Terebralia sulcata*	*Telescopium telescopium*	*Nerita balteata*	Total (density molluscs.m^{-2})
1A	-	-	-	-	-
1B	-	-	-	1	1 (4.00)
1C	-	-	-	-	-
1D	-	-	-	-	-
2A	-	-	-	-	-
2B	-	-	-	-	-
2C	-	-	-	1	1 (4.00)
2D	-	-	-	-	-
3A	-	-	-	-	-
3B	-	-	-	-	-
3C	-	-	-	-	-
3D	-	-	-	-	-
4A	-	2	-	-	2 (8.00)
4B	-	-	-	-	-
4C	-	-	-	1	1 (4.00)
4D	-	-	-	-	-
5A	-	-	-	-	-
5B	-	-	-	1	1 (4.00)
5C	-	-	-	-	-
5D	-	-	-	-	-
6	-	-	-	2	2 (2.00)
7	-	-	-	1	1 (1.00)
8	-	-	-	3	3 (3.00)
9	-	-	1	1	2 (2.00)
10	-	-	-	2	2 (2.00)
11	4	1	-	9	14 (0.56)
12	-	2	-	5	7 (0.28)
13	-	-	-	5	5 (0.20)
14	1	5	-	1	7 (0.28)
15	1	14	2	5	22 (0.88)
16	11	38	11	40	100 (0.16)

case of the macromolluscs, it is possible we became less accurate in sampling the larger quadrats and tended to overlook some of the animals. However, we believe our sampling was accurate and did actually represent absolute densities of molluscs. As such, it would appear that the random location of small quadrats provided inaccurate results if, by chance, they were located over an aggregation of animals, providing high density estimates.

The main advantage of using quadrats is that data is presented in a readily interpretable two-dimensional format (ie. animals.m^{-2}). For crab sampling, the 1 m² quadrat is easy to use because it is about the maximum comfortable length for samplers to reach across. Quadrats of this size are appropriate considering the escape behaviour of sesarmid crabs as the crabs do not run far when disturbed, usually to the nearest burrow. Once in the burrows the crabs position themselves at shallow depths rather than hiding deeper down, allowing them to be grabbed, with little digging. Mollusc densities appeared not to be accurately measurable with smaller quadrats, so that large quadrats should be used, although there was insufficient data from all the quadrats to enable an appropriate comparison.

We concluded that the density estimates of crabs on the mangrove forest floor in Darwin was not significantly affected by the different quadrat sizes we chose, although the most precise method was a 1 m² quadrat sampled 0.25 m² at a time. Because of the burrowing and hiding behaviour of crabs, we could not assess accuracy. We could not assess the most suitable quadrat size for macromollusc density, as what were assumed to be accurate density estimates, significantly declined with increasing quadrat size. Even though the most precise method was the use of 1 m² quadrats, they were probably not accurate because they did not reflect the spatial distribution of the molluscs.

It would have been preferable to locate the smaller quadrats within the boundary of the 625 m² quadrat so that the same animals were counted by different quadrats. This would have greatly assisted in establishing the accuracy of our sampling. Even so, the results of this study reinforce the importance of choosing sampling units that are "large with respect to the scale of aggregation of organisms" (Andrew and Mapstone 1987). Randomly placed small quadrats may be inappropriate or inaccurate even though they can be more precise. It may be that even larger quadrats than we tested are required to accommodate the spatial distribution of these molluscs and therefore provide accurate density estimates.

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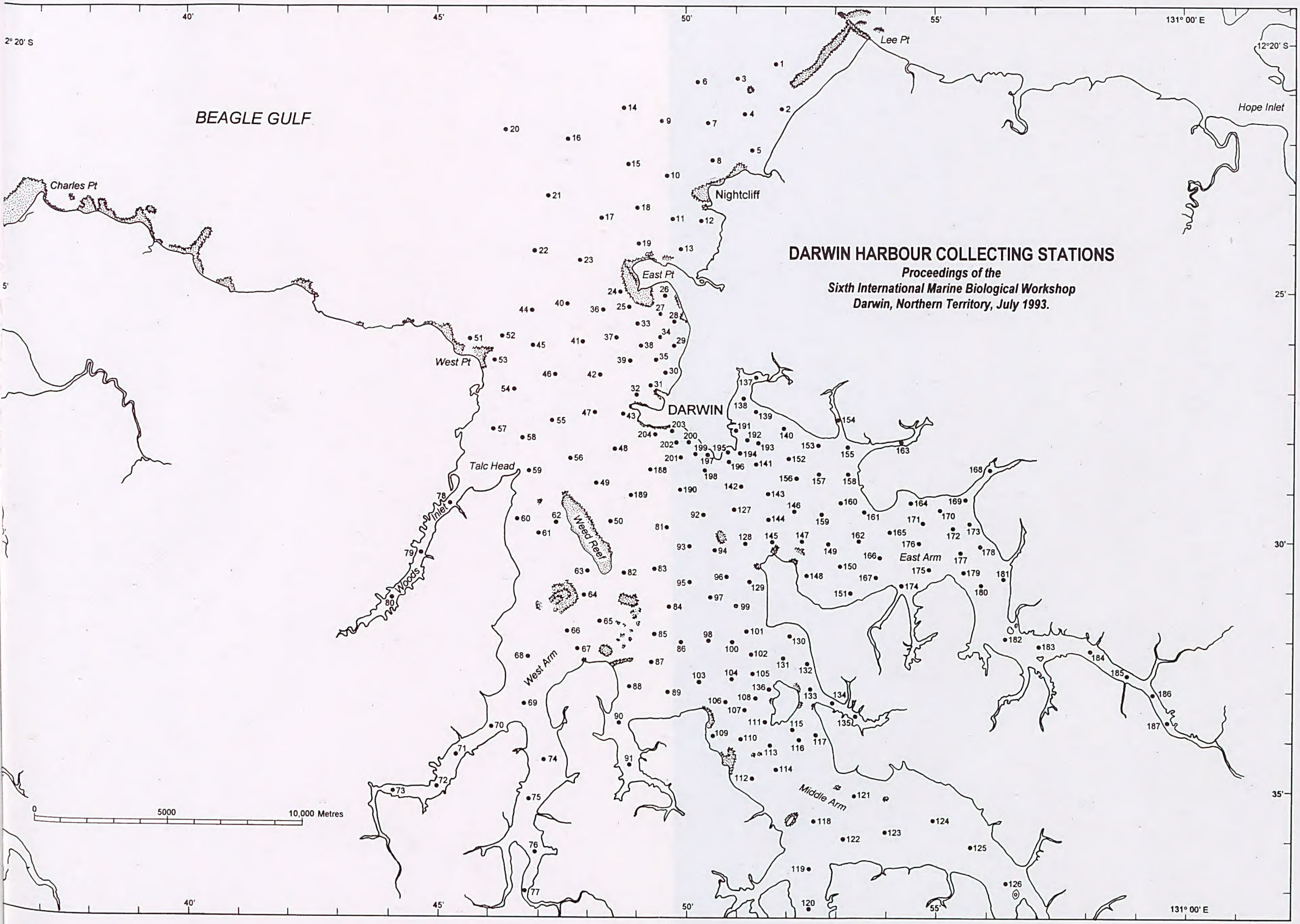

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